PUBLISHER'S COLUMN

The first issue

A new magazine is not a thing that the publisher just dreams up and produces on the spur of the moment: the processes preceding its birth and the moment of decisive action are long and complex. Probably the most important single variable in this is the problem of establishing a need. On CONTROL we went to extraordinary lengths to answer the question and after hundreds of talks with men in the control and instrumentation business—top management, students, control engineers—we found everywhere that it was 'yes'. Our investigations established beyond doubt that by covering the whole field in the way we intend we would be meeting a widespread demand.

Having established the 'why' of the magazine, the next thing was 'how'. We already knew from our brilliantly successful NUCLEAR POWER that the one sure formula was quality from front cover to back and we went to unprecedented lengths to secure the services of an editor, editorial advisory board and staff capable of setting and maintaining the highest possible standard.

The third question of course is 'when', and the answer to that is 'now' as you can see from the following pages.

In introducing this first issue of a completely new magazine we would like to mention just one man without whose enthusiasm and help it would have still remained just an idea. When this was put to Dr Denis Taylor, it was his immediate response that started things going and throughout the long period of gestation it was Taylor to whom we fled with our problems, our worries, our uncertainties.

CONTROL

JULY 1958 VOLUME 1 NUMBER 1

IN THIS ISSUE

SPECIAL FEATURES

REGULAR FEATURES

ROWSE MUIR PUBLICATIONS LIMITED
3 PERCY STREET, LONDON, W1, MUSEUM 8252

CONTROL JULY 1958 VOL 1 NO 1

Manifesto

What are the aims of CONTROL? In this new journal we intend to give the control engineer and the technically interested user of automatic control equipment information and news which can at present be culled only from many periodicals—if indeed they can be found at all.

The 'control engineer': the implications of this term are really the dominant features in the landscape that stretches ahead of CONTROL, and which its future issues will describe and interpret. It is not a term used widely in this country at present. Yet we sense that the quickening development of instruments, techniques and systems for industrial process and position control, for data processing, for the control of aircraft auxiliaries, and for the guidance of missiles, is being matched by the emergence of control engineering as a separate discipline. No less an authority than Sir Harold Hartley, one of the greatest and most far-seeing engineer-scientists of our time, has recently flung down the gauntlet in the cause of this new discipline. A message from him to CONTROL and a report of his recent Presidential Address to the Society of Instrument Technology appear elsewhere in this issue. We remember his successful championing of chemical engineering not so many years ago and the great demand from industry for trained chemical engineers today. It requires no prophetic skill to appreciate that British industry will soon be calling for qualified control engineers at a rate far higher than that at which they can be trained, unless considerably more universities and technical colleges take up the subject seriously.

In CONTROL therefore we shall give the design engineer technical information from all parts of the field of control engineering, so that the man who ploughs his furrows near one side may have a chance to glean from all over it. The true control systems engineer does not think of process control, kinetic control, data processing, cybernetics, etc, as being fenced off from each other. Nor, of course, does he think only in terms of pneumatics, hydraulics, electronics, etc; he must be able to produce the most economic control system to satisfy the technical requirements of an application by using one or more techniques.

But CONTROL aims also at the users: consulting engineers, development engineers, plant engineers, production engineers, without detailed knowledge of instrumentation and control systems; works executives; Service officers, etc. Each issue will contain some general articles which will appeal to those who work with and are interested in automatic control equipment and to those who are wondering how such equipment might help them. Automatic control systems are not the cure-all for every industrial ill, and they will be installed only when they appear to be economic. But managements and consulting engineers are much better able to assess the economics of automatic plant when they know something about its operational possibilities; here, we think, CONTROL can help.

We hope you will look at the following pages carefully and let us know what is right, what is wrong and what other features you would like. 'Be what you would seem to be' was the Duchess's moral for Alice, and perhaps it is not bad advice for any journal setting out to explore the wonderland of control technology.

SIR! LETTERS TO CONTROL

The Editor welcomes correspondence for publication

The instrument industry—growing and ready

SIR: The recent international Instruments, Electronics and Automation Exhibition, held at Olympia, illustrated the rapid strides that have and are being made in instrumentation and control. The Exhibition was sponsored by six leading trade associations and the interest created was most encouraging; this new journal will do much to meet the demand for up-to-date news of the many forms of control systems.

The instrument industry is ready to asist all other industries to make the fullest use of instrumentation in order to control their production. New methods of doing this are possible by the use of improved instruments with increased sensitivity and accuracy, which enables control to be maintained to very close limits; the result is that the standard of the product is improved and production increased.

The growth of the instrumentation and control industry has been remarkable but we must maintain this progress as new developments take place. The enthusiasm shown by everyone concerned will undoubtedly ensure that the industry will maintain its lead, creating more and more business to the benefit of manufacturer and user.

I am sure that this new journal will be welcomed by all industries and I wish CONTROL every success for the future.

E. W. SEMMENS
Chairman, Instrument Section of the British Electrical and Allied Manufacturers' Association; IEA Exhibition Committee.

A challenge to CONTROL

SIR: On first learning of your intention to publish a new journal in the field of instrumentation, my reaction, like that of many of my friends, was tempered with some dismay at yet another periodical. To use a colloquialism, too many consist of advertisements plus 'band-wagon copy' and too few consistently attain the high standards of technical journalism that impart significant impetus to a growing technology.

To be virile, a technical journal must be educative at all levels from the apprentice to the senior professional engineer. I am using the word 'education' in its most literal and not its hackneyed sense. An article dense with mathematical symbols, demanding stern mental discipline before a well-trained reader can assess its meaning, is not educative; nor are new facets of understanding revealed if, after ploughing through 90 pc of the pages which are devoted to advertising, the page area allotted to technical articles consists of 60 pc eye-catching photographs, 15 pc headlines and 25 pc small print dealing so superficially with the subject as to be an insult to the intelligence of any engineer.

There is a great need for a steady flow of competent articles describing practical limitations, means of overcoming difficulties and the application of theory to design, measurement, installation and maintenance.

This country, we find, produces *per capita* less than one-third as many engineers of corporate or graduate standard as Russia. In reply to a question in Parliament on the 17th March, the Parliamentary Secretary of the Ministry of Labour and National Service, Mr R. Carr, said that last year at least 300 vacancies for secondary school teachers in science and mathematics could not be filled. Moreover,

the estimated rate of increase in demand for these teachers during the next few years is an additional 500 per year.

That an onslaught on our nation-wide teaching organization is long overdue in the interests of the country's economic survival cannot be denied by thinking people. That control engineering is intimately related to both the standard of technical education in the country and to the immediate prosperity of these islands is not so widely accepted and its greater realization outside instrument circles is important. Sir Harold Hartley's Presidential Address to the Society of Instrument Technology this year is particularly relevant and stimulating. Sir Harold argues a case for recognition of a new primary technology —control engineering. The exponents of this technology will welcome, use, and be inspired by, a worthy forum in which a catalytic exchange of both theoretical and practical ideas follows from skilful and purposeful editorship.

Good technical journalism is probably the most difficult and exacting branch of the scrivener's art. Nothing less is tolerable. The utter simplicity of the apt title you have chosen is, I hope, a symbol of clear thinking and lucid exposition. In what I have just written I have given a challenge and at the same time pointed to the handle of the weapon which I suspect is already in your hand. I shall therefore await your first issue with more than usual interest and wish you a long and exceptionally successful career. D. C. NUTTING

Solartron Industrial Controls Ltd.

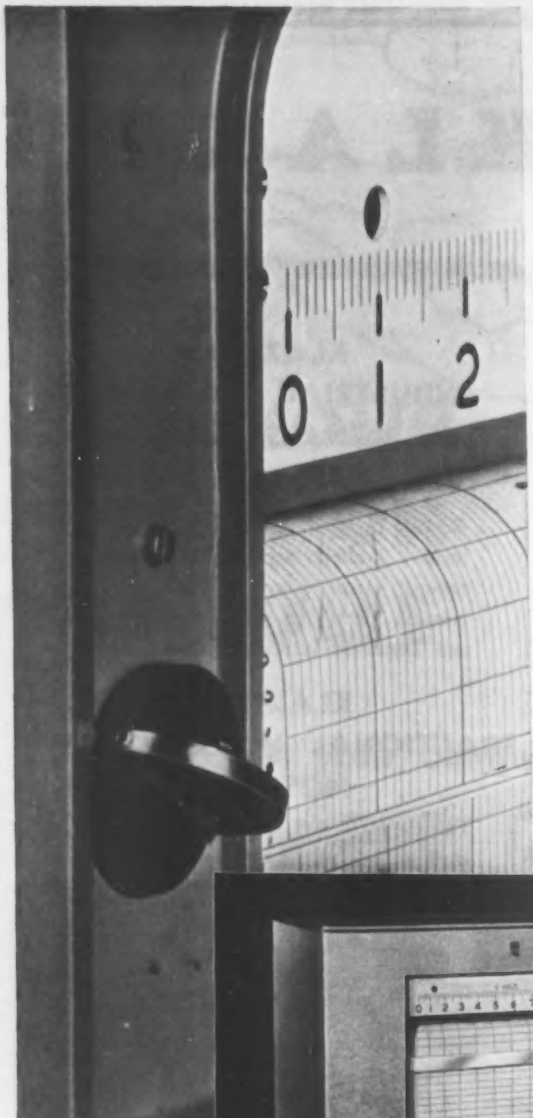
Excitement ahead

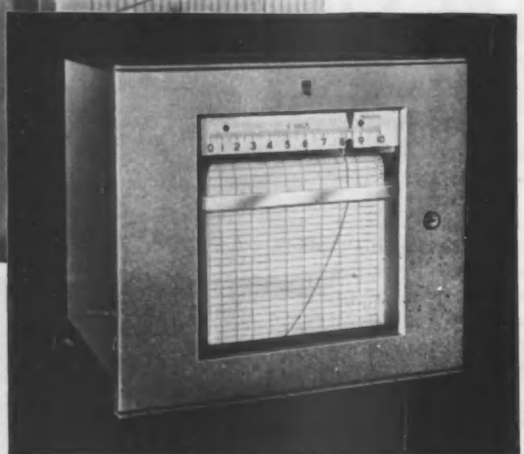
SIR: The recent spectacular advances in control technology have given rise to a rapid increase in the number of publications in the field and it is clear that an attempt must be made to bridge the gap between the research worker and the development engineer. The widespread industrial application of automatic control and allied systems stresses the importance of presenting up-to-date information in a form which can be readily understood by the non-specialist, and I feel that you and your editorial consultants, in launching your new journal, will play a most significant part in satisfying this requirement.

It is not fully appreciated that the subject of automatic control now embraces a large number of topics and disciplines, ranging from the applications of the high-speed digital computer on the one hand, to pneumatic and hydraulic controllers on the other, and the new tools available will expedite considerably the efficient use of instruments and control systems in many fields. It seems to me, however, that the present time calls for an assessment of the many achievements in automatic control and a pause to consider where the most fruitful avenues of investigation now lie. For example, it is most probable that the technique described as 'evolutionary operation' will have an important impact on control system technology, not only in chemical process control where it originated, but also in many other industrial operations. And the idea that it is not sufficient to stabilize a process but rather that it must be optimized must be the goal in the future. This will almost certainly call for the handling of several variables with consequent increasing difficulty in the analytical investigations. Fortunately, complex control systems can often be represented by simulators and models and the impact in this connexion of the modern analogue and digital computers will be considerable. Nevertheless, we must seek more profound concepts in the study of multi-variable control systems and doubtless these will be propounded within the next few years.

All this goes to show that control system technology is entering a most exciting phase of its evolution and there

Tick **No 40** on reply card for further details





To position the chart with hair-line accuracy, it is only necessary to disconnect the chart-drive by means of a simple lever, and to adjust the position of the paper with the knob shown above. Returning the release lever re-engages the drive, which is through a four-speed gearbox.

Start right with PHILIPS potentiometric recorders

Philips potentiometric recorders are *trusted* instruments. Whether applied to experimental and behaviour studies, for building into equipment or to industrial process control they have earned the confidence of the most experienced users.

If you are concerned with the measurement, recording or control of any variable such as temperature, conductivity, strain, vibration, pressure, radiation or any phenomenon to which a transducer or other primary measuring element is responsive, get to know about potentiometric recorders by Philips.

Operating on the servo-operated null-balance principle, Philips potentiometric recorders are available as single-channel instruments, in double-channel form and as multiple-channel recorders up to twelve positions. From a comprehensive range there is an instrument to meet every need. Write now for fully descriptive literature.

Sole Distributors in U.K.

RESEARCH & CONTROL INSTRUMENTS LTD

Instrument House · 207 King's Cross Road · London W.C.1

Telephone: Terminus 8444

Regd. Trade Mark of Philips Electrical Ltd.

(RCIL0350)

SIR!

could not be a more appropriate time for the launching of CONTROL. A. PORTER
Imperial College of Science and Technology.

Bee-line approach?

SIR: I, in company with many other engineers in many fields of action, welcome the introduction of a journal devoted specifically to control and wish it all success. I have no doubt that you will experience no shortage of well-meant advice about the contents and policy of CONTROL, and I have no hesitation in offering my contribution now, when my comments can truly be construed as well meant, and not misconstrued as criticism!

First, I look for a journal which at last will organize the large and ever-growing body of information on control equipment and methods, and, as part of the process, will organize itself so as to present the information in a form digestible by busy people who are by no means all versed in the subject. Can we have articles which do not meander through avenues of advertisements, or leap frog to a conclusion somewhere in the bargain advertising basement? Can we avoid 'clever' presentation—you will know what I mean. Can we have illustrations and captions making their point without the need for thought transference?

Secondly, may I now be rather more constructive and suggest that you give special consideration to the following. 1. The inclusion of factual and technical information in a section which can be divorced from the journal for the purpose of filing without the need for scissors, and without emasculating the rest of the journal. 2. The inclusion of ample information about the availability of equipment, i.e. a good buyers' guide.

My last request is the obvious one that you provide ample facilities for those with bees in their bonnet to unload them onto your readers. W. ROBINSON
British Electrical Development Association.

Authors, not editors

SIR: As one who is horrified by the frequency with which new technical journals are launched, I was not a little sceptical when I first heard rumours about the advent of CONTROL.

There are all too many journals which fill their editorial pages with rehashed press releases and official hand-outs, 'reviews' (extracts from catalogues) of exhibitions, extracts from the *Official Journal* (*Patents*) and similar publications, and a variety of 'news' items ranging from company appointments to lists of forthcoming meetings of learned (and not so learned) bodies. Sandwiched among this assemblage of second-hand material, which is also laced with as much advertising as possible, are a few pages of 'real' editorial—the two or three technical articles which, for the reader, constitute the journal's justification for being in being. These articles are the ones which are written by authors, not editors, workers in the field, not commentators on it. It is these articles which, in the long run, determine most of the value and the readership of the journal.

Now, sir, CONTROL wants, indeed must have, the best readership possible if it is to achieve the recognition and influence which alone can justify its continued appearance. Therefore CONTROL must maintain a good ratio of 'prop articles to all its other contents. I know that this has been most carefully planned and, judging from the performance of another technical journal from the same stable, I am confident that the plan will materialize.

Therefore, sir, in spite of my horror at the increasing number of technical journals in the world, I send you, your staff, and the publishers of CONTROL my very best wishes at the start of your new venture.
Elliott-Automation Ltd. B. M. ADKINS

INDUSTRY'S VIEWPOINT

A monthly article by a prominent man in the control industry on a subject chosen by himself

Mental aberrations in plant control

by **COMMANDER SIR DAVID MACKWORTH, BT, R.N.,**

Sales Manager, Process Control Division, E.M.I. Electronics Ltd

Whilst considerable thought has been given to the design of control devices for complex industrial plants and some of the limitations of such devices are becoming established, it does not appear that a comparable effort has been expended on the study of the human operator which such devices aim to replace.

The human control of, say, a chemical plant involves the combination of a number of mental processes. A particular system of logical deduction must be mastered and applied to the interpretation of plant information and to the appropriate operation of the controls. Past operating experience must be memorized and applied where logical interpretation breaks down. In addition to this, a further logical process must be applied to decide when to operate on a basis of logic and when on a basis of memory, or on a mixture of both.

All these mental processes require organized thought and it is well established that the power to apply organized thought accurately varies not only between individuals, but over quite short periods in the same individual. We can, therefore, start by considering the effect of these short-term and individual-to-individual variations on the operation and therefore efficiency of the plant. This sort of study has already been applied in a number of fields, and some, at any rate, of the relevant causes are reasonably well understood. There is, however, in addition some evidence of what might be called occasional or long-term aberrations which may well be very much more important. In general, these aberrations appear to take the form that an adequately trained operator, supplied with sufficient information to indicate the onset of an abnormal condition demanding abnormal control action, fails to react to this information until the abnormality has increased disastrously.

A common feature in every example of this effect is that it arises after continuous normal operation of a plant over prolonged periods of months or years, during which only normal control action is necessary. This appears to build up an inhibition preventing a rapid switch by the operator from the normal to an abnormal control procedure, although the latter may be well understood and backed by experience. In addition, one may expect to find other inhibiting factors since the switch from normal to abnormal procedure generally exacts some penalty such as reduced operating efficiency or even a temporary cessation of the controlled process.

This type of aberration is best known as occurring in marine pilotage when the conditions are those of prolonged operation by the watch officer during which normal control actions are performed. In a number of well-established cases, the onset of abnormal conditions, such as an impending collision, has been met with a strongly inhibited response. Instead of some large change in course or speed (or both) which would easily have avoided the impending danger, the situation has often been met by a succession of small changes in the course of the ship, and this type of response has been continued to a point where disaster was unavoidable.

The importance, and even the existence, of this sort of occasional aberration in chemical or other industrial plant operators, is at present largely speculative. Naturally the managements concerned would be reluctant to publish details of the consequences of such human errors. Nevertheless, such evidence as exists leads one to suspect that this type of aberration and consequent plant derangement has occurred in industry.

If this is so, there would seem to be two good reasons for starting some serious investigations into this human aberration. First, a better understanding of the mechanism of it is needed so that due allowance can be made when designing operator tasks. Secondly, it may well be vital in assessing correctly the economics of automatic process control systems.

. . . welcome to

CONTROL

from the **Rt Hon Aubrey Jones, M.P.** *Minister of Supply*

We have moved in the last two decades into a new world. Some say that we are witnessing merely the culmination of the industrial revolution of two centuries ago. I think it is truer to say that we are witnessing a new industrial revolution. Since 1945, and largely because of the impetus given to electronic development during the war, the tempo of development has been extraordinarily fast. Control engineering and the allied techniques are the keys to the new world. It is vital that this country should have these keys. It is necessary if we are to raise our standard of living, if we are to preserve—let alone extend—our export markets, and if we are to remain capable of defending ourselves.

I am sure that CONTROL will serve a most useful purpose in keeping both our own industrialists and our foreign customers aware of the ever widening field of techniques and aids to efficiency in industry and transport, and of the many and varied applications of such aids. I wish it all success.

Aubrey Jones

from **Sir Harold Hartley, G.C.V.O., C.B.E., M.C., F.R.S., Hon. M.I.E.E.** *President of the Society of Instrument Technology, 1957–58*

I send you my best wishes for your new venture CONTROL, which is to be devoted to control engineering. You know from my recent Presidential Address to the Society of Instrument Technology that in my view the time has come when this new branch of engineering should be recognized as a primary technology. It has developed its own discipline and philosophy which are finding applications over so wide a range of human endeavour. British technologists are making outstanding contributions in this field, which is of increasing importance to the future of British industry. I therefore welcome your journal, which will provide another shop window for British contributions and arouse and educate public interest in this new phase of industrial development.

Control engineering is among the most rapidly growing industries. Its products embody one of the largest proportions of brain power and are therefore of special significance for our export market. By securing an international circulation CONTROL can give most valuable publicity for British industry.

There is too the important question of recruitment at the three levels, the technologist, the technician and the instrument mechanic. I hope that you will devote some space to the educational problems that control engineering is now facing, and the opportunities it offers for able young people at each level. Three recent events seem to me good omens for its future: the appointment of Mr Ream to a Readership in Control Engineering at the Battersea College of Technology, the approval of the first Dip. Tech. (Eng.) Course in Instrument and Control Engineering at the Northampton College of Advanced Technology, and the decision to institute a Chair in Control Engineering at McGill University. So good luck to CONTROL and more power to its elbow.

Harold Hartley

from **R. Barrington Brock,** M.B.E., B.Sc., F.R.I.C. *President of the Scientific Instrument Manufacturers' Association*

I was very pleased to receive a prior notification of the publication of your new journal, and I am glad to have this opportunity of welcoming it to the ranks of the technical journals which do so much to publicize instrumentation in general.

I feel that the technical Press, and particularly your type of journal, will have an increasing effect in educating the great number of semi-technical and non-technical executives in the smaller companies.

I think it is beginning to be appreciated that the big firms are already fully conversant with the advantages which they can obtain by using modern scientific equipment. I feel, however, that the future requires greater and greater efforts to prove to the non-technical firms that a vast improvement in product, or decrease in cost, can be obtained by suitable instrumentation of their processes.

We know, as an industry, how difficult it is to persuade a firm which has made the same product for a generation, without adequate instrumentation, that it will pay them in hard cash to become more scientifically minded. I feel that proper presentation of the facts, in a readable manner, by your type of journal, can only bring benefits to industry and the whole country.

I wish you every success in your new venture.

R Barrington Brock.

from **Sir Norman Kipping,** J.P. *Director General of the Federation of British Industries*

Automatic control engineering and its application to industry are of such great importance today as to need no emphasis. Not only is it patent commonsense that mechanical repetitive work by human beings should be replaced wherever possible by integrated and automatically controlled machines, but it is vital to our survival as a trading nation that our progress in this field should not lag behind that of our competitors.

Automation has possible applications to all sizes of industrial establishments; and to any sphere of human activity which is repetitive in some way. The electricity supply industry has of course already gone far along this road, and some process industries like oil and chemicals are well on the way.

But much remains to be done. Although automatic mechanisms are as old as the medieval striking clocks of the fourteenth century, it is only in the past few decades that the implications of early ideas have been appreciated and applied with the help of the new science of electronics to a more widespread linking and controlling of machines. British industry itself is making great strides in this field and I see no reason why we should be over-modest about our successes. I therefore welcome the launching of CONTROL as a worthy attempt both to inform British industrialists of applications of automatic control engineering of use to themselves, and to see that countries overseas know what Britain is contributing to the progress of automation.

Norman Kipping

from **L. S. Yoxall** *President of the British Industrial Measuring and Control Apparatus Manufacturers' Association*

The advent of a new technical journal dealing with control engineering will be welcomed by instrument manufacturer and user alike. It arrives at a propitious moment, for the British instrument industry has reached an important point in its development.

Only twenty-five years ago the British industrial instrument maker had to work very hard indeed to convince manufacturers of the benefits to be derived from even the simplest forms of instrumentation. How the picture has changed. Today the importance of the instrument industry in the economy of our country cannot easily be exaggerated. There is now hardly a manufacturing process which does not depend, in greater or lesser degree, on some form of instrumentation. This transformation has been brought about by a great many factors, not least the contribution of the technical Press. Even so, our industry is still, comparatively speaking, in its infancy and this new journal can play an important part in the further expansion which lies ahead.

The results of the Instruments, Electronics and Automation Exhibition held in London in April of this year underlined the vast potentialities of the overseas market for British instrumentation. Visitors from all parts of the world showed an interest in our products which must not go unsatisfied.

With a strong editorial team and an advisory panel including some of the most respected names in our industry, CONTROL starts off with every advantage. I therefore welcome this new journal in the hope that it will nurture and sustain this valuable interest.

CONTROL has my best wishes for its success.

L. S. Yoxall

ELECTRONIC SYSTEMS FOR INDUSTRIAL MEASUREMENT AND CONTROL—1

by **M. V. NEEDHAM,** *Assistant General Manager (Industrial) Elliott Brothers (London) Ltd.*

Many new installations of industrial process plant now use electronic control apparatus. Here a control systems engineer who has been much concerned with the planning of electronic systems begins an authoritative review of them, with particular reference to an a.c. design.

1. Introduction

For many years pneumatic methods have been used almost exclusively for plant control in the continuous process and other industries. Today a wide range of instruments and equipment for pneumatic control is commercially available, and as a result of its long history of development, based on extensive field experience, this equipment is reliable, accurate and inexpensive. Its nature is such that it is readily understood by staff with reasonable mechanical training and its maintenance presents no very serious problem.

Although alternative systems, based on electronic techniques, are possible, their introduction has progressed slowly, since, until recently, no compelling reasons have existed for abandoning the well-tried, familiar methods. Occasionally, it is true, measurement problems arose where solutions by electronic methods were essential, but their widespread adoption was inhibited by the idea that electronic equipment was delicate and unreliable for arduous duty under plant conditions. With improvements in electronic valves and components, and as the techniques have become more familiar, this situation has changed: today adequate evidence exists that correctly designed electronic equipment is as reliable as its pneumatic counterpart. Moreover, other factors have emerged which often make electronic instrumentation and control systems essential.

2. The need for electronic methods

Electronic techniques were first introduced into process control to satisfy the need for certain measurements to which pneumatic techniques are not suited. A typical example is the measurement of pH-value for which electronic techniques provide the only suitable solution. Other examples are conductivity measurement, gas analysis, etc., where electrical signals are also obtained. Where such measurements must be included in a control scheme, conversion to a pneumatic signal is necessary and this often involves considerable complexity. The desire to increase the sensitivity or speed of response of measurement has also dictated the use of electronic methods. The well-known electronic, self-balancing recorder stems from such considerations, and although originally designed for temperature measurement it is now confidently used in a variety of applications. In these ways the introduction of electronic techniques has been progressing steadily, but recently additional reasons have become important. Many plants, notably in the oil refining and chemical industries, have increased in size and complexity—a trend which will no doubt continue. The cost of installation of pneumatic piping and, in open-air plants, the freezing of condensed moisture with consequent pipe blockage, are serious problems. Moreover, the desire to adopt centralized control increases the length of piping runs. This aggravates these problems and in addition increases signal transmission lags which complicate system stability and sometimes limit the speed of plant control. The large amount of data accumulated in complex plants necessitates the adoption of automatic logging devices requiring electrical inputs. This also applies to electronic computers which will be used, in conjunction with continuous quality analysis instruments, as essential elements in realizing truly optimized plant operation.

It is natural that all these developments have led to thoughts of replacing pneumatic methods by electronic methods, since so many difficulties are then avoided. In fact, completely non-pneumatic control systems have already been installed and are giving satisfactory performance. However, the fundamental issue, whether, and in what circumstances, they are preferable to the well-tried pneumatic ones, is not always easy to resolve. Both have their adherents, and, as so often happens when new ideas are introduced, extremes of enthusiasm are encountered. No doubt a situation will be reached eventually in which 'peaceful coexistence' is possible, and with careful, informed consideration of each case on its merits, industry will be richer by yet another wisely applied technique.

In the following, the general principles of the currently available electronic systems are surveyed briefly, so that the reasons for the design of the particular system, selected as an illustration, can be better appreciated. As will be seen, several

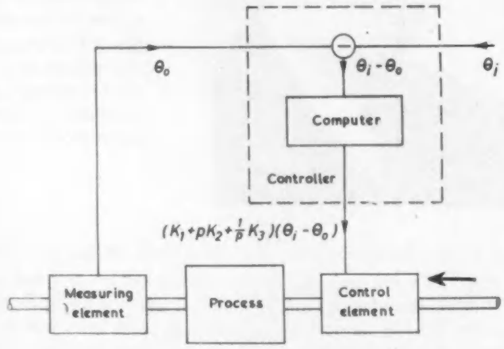


Fig. 1 A simple automatic control loop

alternative techniques are available which complicate the problem of standardization. This is an important outstanding problem but more field experience is necessary before a lasting answer can be achieved.

3. Some general principles

Most plant control depends on a closed-loop system such as that shown diagrammatically in Fig. 1. It consists of a measuring element, a control element and a controller. Any deviation between the measured value θ_0 and the set-point value θ_i is detected in the controller, which provides a signal capable of adjusting the control element so that the deviation is reduced to a small value. The signal computed by the controller must be such that the required accuracy and speed of control are obtained together with loop stability.

In general the controller should be suitable for one-, two- or

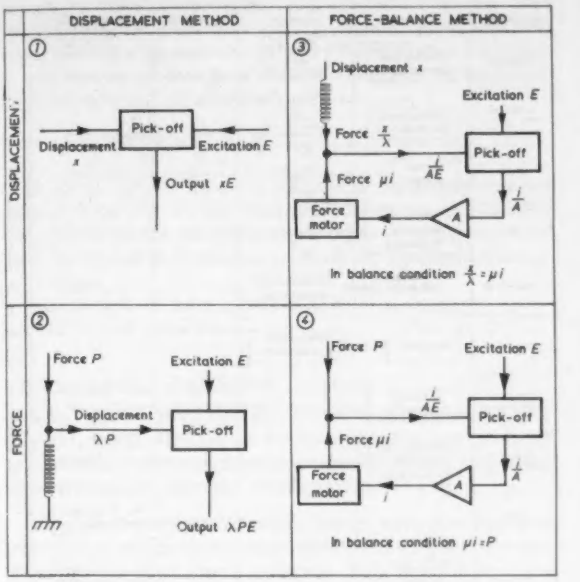


Fig. 2 Measurement of displacement and force

three-term control; in the three-term case its output should be of the form:

$$(K_1 + K_2p + K_3/p)(\theta_i - \theta_o)$$

where $p = d/dt$ and K_1, K_2 and K_3 are constants determining proportional band, derivative action and integral action respectively.

The set-point θ_i must be capable of manual adjustment. Sometimes, however, it is automatically adjusted to a predetermined programme or in proportion to some other measured variable. To allow for setting-up, fault or other abnormal conditions, a manual control of the signal fed to the control element is included. For simple proportional control an adjustable bias of the control signal is introduced to reduce any offset error to a small value. Facilities for local and remote indication and for recording are often required.

In the design of such a control system using electronic techniques a choice of methods is available for each of the elements. These affect the transmitted signal, measurement methods, the controller and control elements.

3.1 The transmitted signal

With pneumatic methods, data are conveyed by the transmitted signal in terms of pressure variations so that standardization is relatively easy; for many years a pressure range of 3–15 lb/in² has been used almost exclusively.

When an electrical signal is used a wider choice exists. Data can be conveyed in terms of current or voltage variation, or, if alternating current is used, by frequency or phase modulation. If pulsed signals are used, amplitude, rate or width modulation are possibilities or a coding system can be employed. Some of these alternatives have been used for long-distance telemetering, but in the commercially available control systems, of the type being considered here, only current or voltage variations of direct or alternating currents have been adopted so far. Nevertheless standardization is a more complicated problem than for pneumatic control.

3.2 Measurement

In process control the most frequently used measurements are those of temperature, pressure, flow rate and liquid level. Any system must provide for these, but, in addition, it should be readily and simply adapted for use with many other measuring elements.

Temperature. Thermocouples and resistance thermometers are already widely accepted and are an obvious choice for use with electronic controls. Both types are directly suitable in a system using a d.c. transmitted signal, but in an a.c. system the use of thermocouples is complicated by the need for conversion from d.c. to a.c.

When amplification is required a stable low-drift amplifier using some kind of 'chopper' is essential with d.c. signals for both types. However, if a.c. is used, an advantage is gained since an a.c. amplifier is possible with resistance thermometers and such an amplifier is considerably simpler than a d.c. one.

Displacement and Force. Two general methods are used for the measurement of either of these quantities. These are summarized in Fig. 2.

In the first, or displacement, method, an electrical pick-off capable of accurate, linear measurement of displacement is used. The use of suitable linkages extends the range of displacement measurement or enables rotations to be accommodated. A force being measured is opposed by a linear spring and the resulting displacement is measured directly. Since the pick-off can be highly sensitive the spring motion can be small.

The second, or force-balance, method makes use of a force motor instead of a spring. This is usually a coil moving in the field of a permanent magnet and is arranged so that the force on the coil is proportional to the d.c. flow in it. A force being measured is opposed by that of the force motor and the current is adjusted until a balance is obtained. This condition is automatically achieved by detecting the force motor movement with a displacement pick-off whose amplified output provides the current to the force motor. The force motor, pick-off and amplifier then behave like a spring and the force motor current is a measure of the applied force. With a high loop gain only very small movements are necessary. The importance of the method lies in the fact that the pick-off need not be very linear or stable.

To measure a displacement with the force-balance method, a stable linear spring must be introduced so that a force proportional to the displacement is applied to the force motor and measured as before.

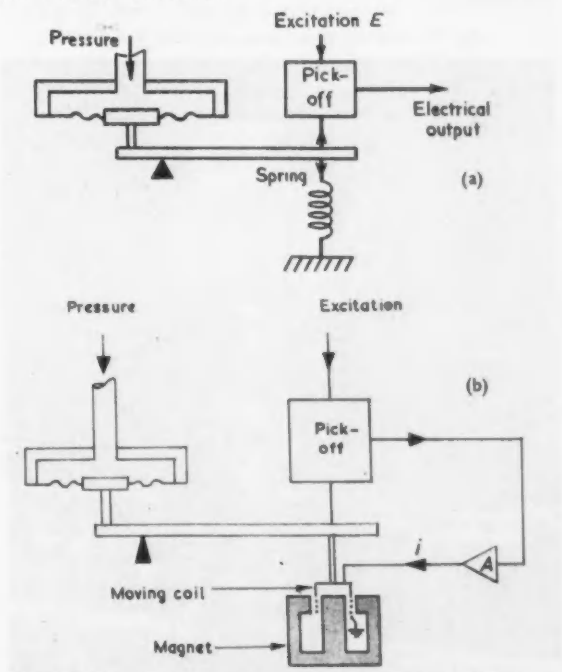


Fig. 3 (a) Pressure measurement: displacement type, (b) Pressure measurement: force-balance type

It should be noted, in the force-balance method, that practical currents and magnet field strengths limit the resetting force, and when large forces are measured a large mechanical magnification of resetting force may be necessary. For some requirements a succession of magnifying levers or a complex linkage must be used, and errors due to friction may then be significant. With the displacement type no such restriction applies and a simpler, more robust design can be realized. In the equivalent pneumatic instruments a large resetting force is possible and the force-balance method may have considerable virtue.

Suitable displacement pick-offs are differential transformers, variable capacitors and variable inductors. These are all essentially a.c. operated devices and indeed, for d.c. operation, no suitably sensitive linear pick-off is available. For this reason the simple displacement method is restricted to the transmission of a.c. signals while for systems with d.c. transmission the force-balance methods must be used. Of the available pick-offs, the differential transformer is the most readily designed with an accurate linear characteristic and it can, moreover, be energized with a.c. at mains frequency. It is described in Section 4.1.

Pressure. The most suitable pressure transducers make use of conventional bellows, diaphragms or capsules. The resulting forces can be measured using either force-balance or displacement techniques as described above. The basic arrangements are shown in Figs. 3a and 3b. Absolute and differential pressure can be measured with similar devices.

Liquid level. Level transmitters using floats or displacers provide a displacement measurement problem which again can be solved by either force-balance or by direct displacement methods. Alternatively, hydrostatic head may be measured using a differential-pressure transmitter.

3.3 Control elements

In industrial processes most control elements are gas and liquid flow valves. Electric motor operation of these is sometimes possible but where speed of response together with large operating force is required pneumatic or hydraulic operators are necessary.

Fig. 4 A self-contained electrohydraulic operator

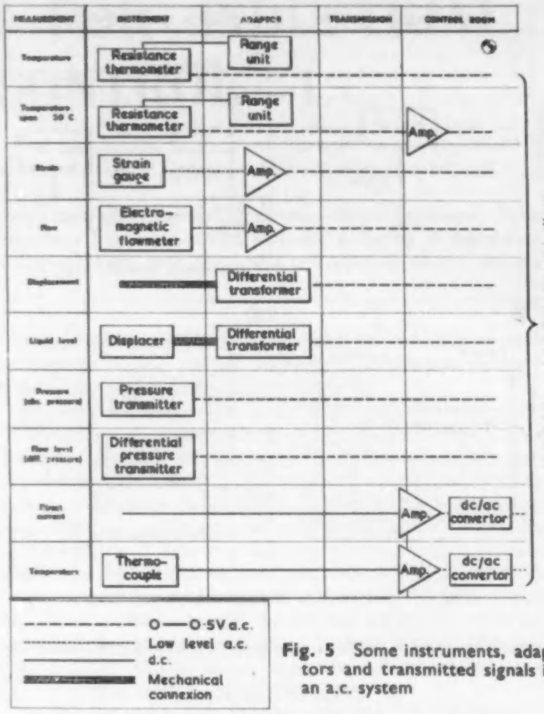


Fig. 5 Some instruments, adaptors and transmitted signals in an a.c. system

In most installations in which electronic controls have been used, the design engineer has found it necessary to retain the conventional pneumatic operator. Thus one of the advantages has been lost, but recently electrohydraulic operators have been developed so that the use of air can now be completely eliminated. A typical example, shown in Fig. 4, consists of a self-contained electrically driven pump and a two-stage hydraulic amplifier controlling oil flow to an output piston. The first-stage valve is caused to move by a coil carrying current in a magnetic field. Installation of these units involves simple wiring for the mains power connection and d.c. input control signal. The valve operator illustrated can provide up to 2000 lb thrust with a frequency response up to 1 c/s. Although more expensive than a pneumatic operator, it obviates the need for a compressor and air drier. Taking into account the relative costs of piping and power supply cabling, the electrohydraulic method is frequently less expensive, and it has a great advantage under freezing conditions.

3.4 The controller

The controller is a means of detecting the difference between θ_i and θ_o followed by a simple computer producing the function mentioned in Section 3. For proportional control all that is required is a variable-gain amplifier with an output stage providing a current suitable for the operation of an electropneumatic convertor, electrohydraulic valve or other control element. So far a d.c. signal has been universally employed for this purpose.

Apart from the need to achieve a reasonably stable gain, the only difficulty is in achieving a low drift of the error-detecting arrangement. For accurate control it is necessary that when θ_i and θ_o are constant there should be a constant output from the controller, and any zero drift causes directly an error in control. Since it is notoriously more difficult to achieve a given low zero drift with d.c. amplification than with a.c., a system using a.c. transmitted signals is essential unless the error signals are so large that zero drift becomes inappreciable.

However, the differentiation and integration of the error

signal, to introduce derivative and integral terms, can most conveniently be performed on d.c. signals, since then the simple relation between the current i flowing into a capacitor C and its rate of change of voltage v can then be exploited. This relation may be expressed as:

$$v = \frac{1}{C}\int i dt, \quad \text{or} \quad i = C\frac{dv}{dt}$$

In an a.c. system the error signal is amplified and rectified before being fed to the electronic derivative and integral circuits. Since the amplified error signal is large compared with the zero drift of these d.c. circuits no significant inaccuracy occurs.

An example of such a controller will be discussed in the second part of the article.

3.5 Comparison of a.c. and d.c. methods

A full discussion of the relative merits of the use of a.c. or d.c. as a transmitted signal would be lengthy, and probably no generally valid conclusion is possible. Some important comparisons are, however, worth noting.

Signal line resistance. In a d.c. system, using force-balance instruments and current transmission, variation of line resistance has no effect upon accuracy. This follows since the amplifier automatically adjusts the current to the force-balance condition irrespective of any external circuit resistance. Where voltage is transmitted, line resistance will affect accuracy only if a load is applied at the receiving end. This is usually avoided since the signals are fed into the grid circuits of thermionic valves.

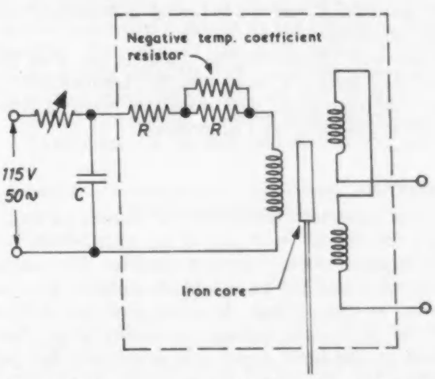


Fig. 6 Basic arrangement of differential transformer

Interference. Pick-up of interfering signals, by induction in the cables, can affect the accuracy and response of the system. In a d.c. system suitable filtering overcomes this but it cannot be used with a.c. signals. However, the use of a closely twisted twin cable with overall shielding minimizes such pick-up, and completely satisfactory results are achieved in practice with a signal voltage of 0·5 V r.m.s. 50 c/s.

Signal transmitters. An a.c. system employs transmitters of the displacement type, using differential transformers, which can be simple and robust. No electronic valves are employed so that maintenance in exposed locations is both minimized and eased. In this way an a.c. system has decided advantages over a d.c. system, which, generally, has the more complex force-balance type of transmitter requiring valves in close proximity to them.

When resistance thermometers are used with a.c. excitation an output signal suitable for direct connexion to the controller can be realized, but the use of thermocouples is complicated in a.c. systems by the need to convert from d.c. to a.c.

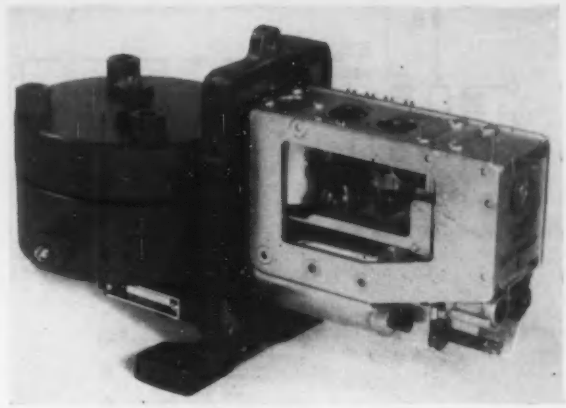


Fig. 7 A differential pressure transmitter. The cover is removed to show the differential transformer and link mechanism

4. A.C. measurement, recording and indication

As an illustration of the use of electronic techniques in process control a particular system will be described in some detail. In its design, the emphasis has been placed on simplicity and robustness of measuring elements since these are very often installed in exposed plant positions. For this reason an a.c. system was chosen. The only thermionic valves in critical service are in units installed in the control room, and by the adoption of a unit construction principle, maintenance is eased and complete flexibility obtained. Transmitters for the measurement of temperature, pressure and flow have been specially designed but simple adaptors enable many other measuring instruments to be employed. The complete system includes recorders, indicators, controllers and an electro-pneumatic convertor.

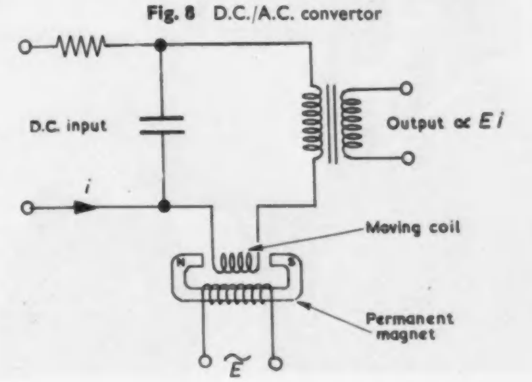
4.1 Measurement transmitters

Fig. 5 shows the elements involved in a number of typical measurements together with the nature of the transmitted signals. Where an item is shown in the adaptor column this is mounted close to the primary transmitter. All transmitted a.c. signals are 0–0·5 V r.m.s., 50 or 60 c/s, with 58° phase lead.

A.C. measurement. When the signal is of suitable magnitude it is transmitted directly. Where necessary an adapting a.c. amplifier is used, as, for example, with strain gauges and the electromagnetic flowmeter.

Temperature. A platinum resistance thermometer is connected in a conventional bridge circuit and provided with a range unit with interchangeable range cards. The resistance of the thermometer element is about 203 ohms at 0° C and 0–0·5 V r.m.s. output can be achieved with a minimum span of 50° C. The range unit is fed from the mains supply and incorporates

Fig. 8 D.C./A.C. convertor



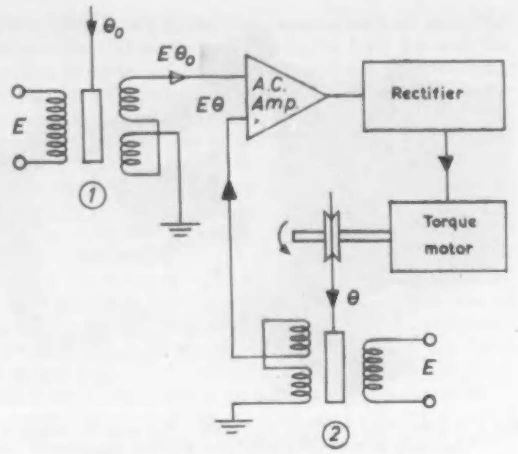
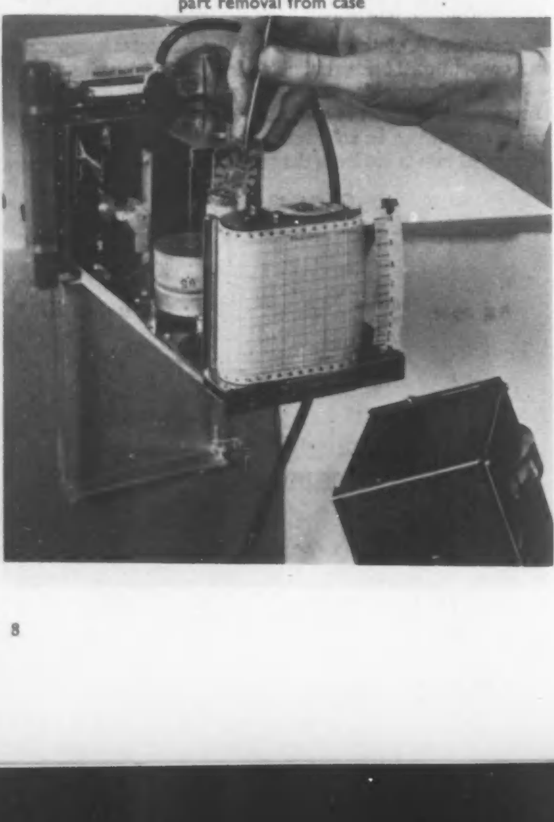


Fig. 9 Servo for indicator and recorder

a network giving the correct phase of the output signal. Once adjusted this requires no further adjustment when range cards are changed. When a span smaller than 50° C is required an a.c. amplifier, normally mounted in the control room, is used.

Displacement. A differential transformer, shown diagrammatically in Fig. 6, is used for the measurement of linear displacement. This has a cylindrical former wound with three separate windings. The two secondary windings are placed symmetrically on the former, so that with the iron core in a mid position equal voltages are induced in each winding; and since the secondaries are in series opposition the net output is zero. Moving the core away from this position results in a net output proportional to the displacement. Resistors are connected in series with the primary so that, with the nominal mains voltage of 115 V, an output of 0·5 V r.m.s. and 58° phase lead is obtained for 0·05 in. core displacement. The variable resistor allows an adjustment of span to be made without significant alteration in phase of the output signal. It should be noted that the output voltage, at any setting of the core, is linearly related to the mains voltage, and, as will be explained, this has no effect on the accuracy of indication or recording.

Fig. 10 A miniature recorder showing method of adjustment by part removal from case



Level. Measurement of level can be conveniently done with a displacer-type instrument in which the rotation of the torque tube is converted to a linear motion of the differential transformer core.

Pressure. Transmitters for pressure, absolute pressure and differential pressure are based on the displacement method discussed in Section 3.2. Fig. 7 shows the differential pressure transmitter in which a differential transformer is used to convert displacement into an electrical signal. A spring pivot is used to provide a fulcrum for the beam and the range spring and differential transformer are coupled to this beam by a linkage of high linear magnification. No pivot or sliding member is used in this linkage so that frictionless operation is achieved.

D.C. measurement. This is necessary when dealing with the outputs of thermocouples, pH instruments, ionization chambers etc, and where necessary d.c. amplification is carried out with a chopper-type amplifier. The essential problem is the conversion to an alternating voltage, having the correct phase, and varying linearly with mains voltage in the same way as the differential transformer and other a.c. transmitters. To do this a moving-coil convertor is used. This, as shown in Fig. 8, is a moving coil, free to rotate in the field of a permanent magnet, around which is a winding fed with a.c. A direct current flowing in the coil causes it to deflect, so changing the alternating voltage induced in it. This induced voltage is proportional to the deflection and so to the direct current. The presence of the capacitor ensures that all the induced voltage appears on the primary of the transformer. This arrangement is quite satisfactory providing the d.c. input is about 100 μA. In view of the a.c. excitation from the mains supply the output has the required dependence on mains voltage variations.

For use with thermocouples a unit is provided having a chopper d.c. amplifier, cold junction compensation and a moving coil convertor. The minimum span is 2 mV and provision is made for zero suppression.

4.2 Indication

For local indication, and where the highest accuracy is not required, the output from any of the transmitters is fed to a unit housing a simple one-valve amplifier. The output from this is rectified and fed via a cathode follower to a moving-coil meter. It will be clear, however, that this indication is subject to the mains voltage variations since these are impressed on the input signal and errors of a few per cent will occur.

When more accurate indication is required, this variation is overcome by using the simple servo technique illustrated in Fig. 9. The differential transformer 1, in say the pressure transmitter, provides an output $E\theta_0$ where θ_0 is proportional to the measured pressure. The differential transformer 2 is driven by a torque motor having a relatively small angular rotation θ and fed with direct current. Its output $E\theta$ is compared with $E\theta_0$, by the a.c. error amplifier. The amplified error is rectified and fed to the torque motor. The movement of the motor alters the position of the core of the differential transformer 2 in such a way as to cause the two voltages to be sensibly equal. Thus $E\theta_0 = E\theta$; i.e. $\theta_0 = \theta$.

The torque motor shaft is coupled through gearing to the indicator pointer whose deflection is θ independently of the mains voltage E. Fig. 10 shows the servo indicator unit.

4.3 Recording

An identical servomechanism is used for moving the pen arm of the recorder so that the recorded value is also independent of mains voltage variations. The recorder chart is 3 in. wide and moves from right to left so that the time

axis on the chart is horizontal. Both the recorder and the indicator are mounted on identical chassis which can be inserted into mounting frames suitable for panel mounting. A unit is available which houses two servo units and provides a two-pen record on the chart. Where a standard 11 in. wide strip-chart recorder is required a differential transformer can be fitted to an electronic self-balancing recorder in place of the usual slide wire.

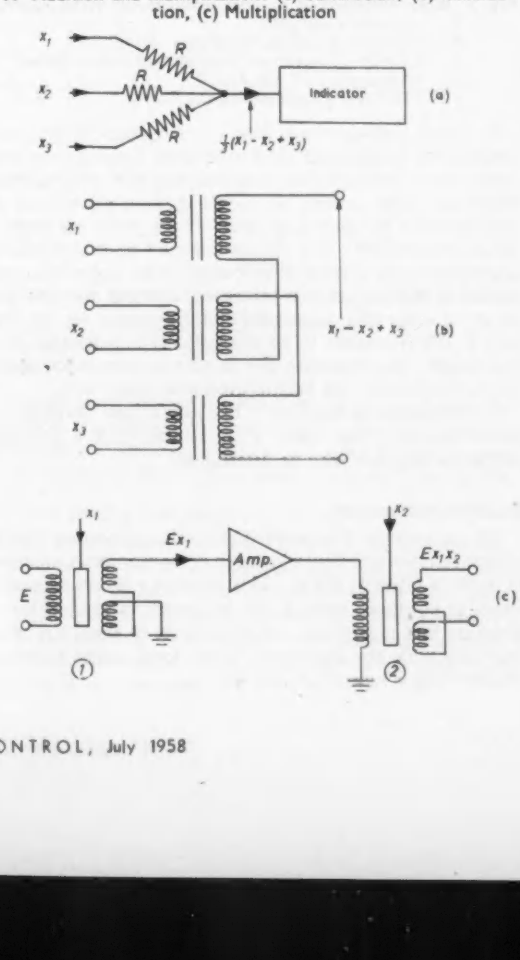
4.4 Simple analogue computation

It is frequently necessary to carry out simple computations with the measured variables, some examples of which are given below:

COMPUTATION	APPLICATION
$x_1 + x_2 + x_3 = X$	Summation of flow rates etc
$x_1 x_2 = X$	Heat output = Flow rate × Temperature rise
	Mass flow = Volume flow × density
$\frac{x_1}{x_2} = X$	Efficiency or yield, e.g. $\frac{\text{Output quantity}}{\text{Input quanity}}$
$\sqrt{x_1} = X$	Linear flow signal from differential pressure of orifice or venturi
$\sqrt{\frac{x_1 x_2}{x_3}} = X$	Linear flow signal corrected for pressure and temperature variation
$\int A dt = X$	Totalizing flow etc

Summation. The simplest method is by resistor mixing. This is shown in Fig. 11a. With equal resistances the voltage at the input to the indicator is the average value $\frac{1}{3}(x_1+x_2+x_3)$, provided that no current is drawn by the indicator. It should be noted that the span of the sum signal is equal to that of the separate variables, but where the true sum is required separate transformers may be fed from the input signals and their secondaries joined in series. In principle any number of variables can be summed in this way and subtraction is possible with both these arrangements by appropriate reversal of the phase, as shown in Fig. 11b.

Fig. 11 Addition and multiplication: (a) Summation, (b) Subtraction, (c) Multiplication



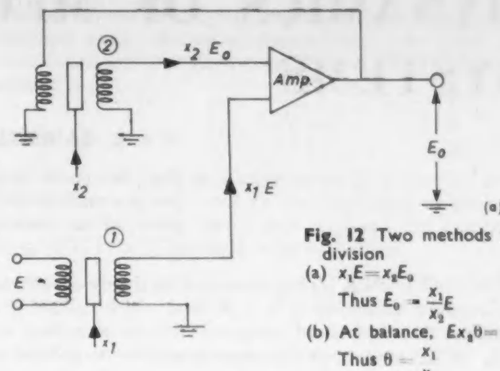
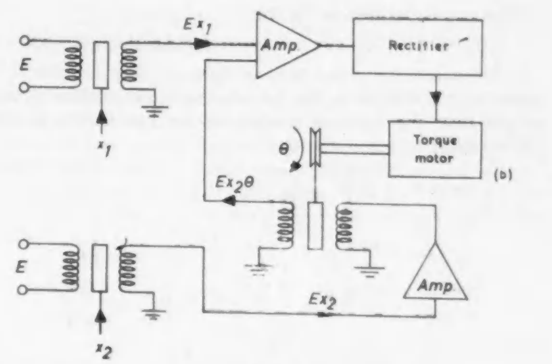


Fig. 12 Two methods for division
(a) $x_1E = x_2E_o$
Thus $E_o = \frac{x_1}{x_2}E$
(b) At balance, $Ex_2\theta = Ex_1$
Thus $\theta = \frac{x_1}{x_2}$



Multiplication. Since the output of the differential transformer is proportional to $E\theta_o$ it behaves as a multiplier of the quantities E and θ_o. The use of this property to multiply two displacements, x_1 and x_2, is shown in Fig. 11c.

The output from the differential transformer measuring the quantity x_1 is amplified and used to energize the differential transformer measuring the quantity x_2. The resultant output is proportional to x_1x_2E and, if the gain A is 230 exactly, the full-scale output of 0·5 V produces an excitation of 115 V for transformer 2. The span of the product output is then correct and can be fed to an indicator or recorder.

Division. Two methods are available for this operation. In the first, shown in Fig. 12a, the output of differential transformer 1 is proportional to x_1E and is fed to the error amplifier together with the output of differential transformer 2, which is excited from the error amplifier output. If the gain is high the system causes the output of transformer 2 to become equal to that from transformer 1, i.e.

$$x_1E = x_2E_o$$

and
$$E_o = \frac{x_1}{x_2}E$$

An alternative method makes use of the servo indicator. In this the feedback transformer is energized with one amplified input quantity and the other quantity is fed normally to the indicator amplifier. The pointer indicator is then equal to x_1/x_2 and, moreover, signals are available separately representing x_1 and x_2. A recorder unit can be used instead of an indicator, and with a two-pen version one pen can be used to record either the variable x_1 or x_2 whilst the other records their ratio.

Methods of finding square roots, squaring and integrating, and some applications of computation techniques will be described in the second part of the article.

DYNAMICS OF MECHANO-PNEUMATIC SYSTEMS

by **J. E. SAMSON**, B.SC., A.INST.P., *Foxboro-Yoxall Ltd.*

For the control systems designer this article describes the application of a theory for presenting the response of pneumatic transmission lines and loads in linear form, to account for the effect of these loads on mechanopneumatic systems

A RECENT PAPER (*1*) has presented the theory of electrical and acoustic transmission in a method which utilizes it to formulate the response of pneumatic transmission lines and loads, of the sizes normally encountered in the process industries, in the form of a general polynomial.

This can be written in the form

$$G_{j\omega} = \{1 + b_1(j\omega) + b_2(j\omega)^2 + b_3(j\omega)^3 + \ldots\}^{-1} \qquad \ldots (1)$$

where $G_{j\omega}$ is defined as the transfer function expressing the output over the input of a transmission line for harmonic disturbances

$$\text{and } b_1 = T\left(r + \frac{1}{2!}\right)$$

$$b_2 = T^2\left(\frac{r}{3!} + \frac{1}{4!}\right) + \frac{TT_1}{2}\left(r + \frac{1}{2!}\right)$$

$$b_3 = T^3\left(\frac{r}{5!} + \frac{1}{6!}\right) + \frac{T^2T_1}{2}\left(\frac{r}{3!} + \frac{1}{4!}\right)$$

$$T = RCl^2,\ T_1 = \frac{2L}{R},\ r = \frac{C_o}{Cl}$$

R, *L* and *C* are the pneumatic equivalents of resistance, inductance and capacitance per unit foot of line, length *l* and C_o is the load (lumped) capacitance.

In presenting the response in the above form, several assumptions are made:

1. Pressure disturbance amplitudes are small.
2. There is no steady flow of air through the line.
3. The load is lumped.
4. Such small disturbances as do occur do not alter substantially the mean pressure level in the line.
5. There is uniform distribution of the resistance, inductance and capacitance parameters throughout the line.
6. The ratio of the specific heats is assumed as 1·1 throughout the line and load (*1*).
7. The resistance parameter is presumed to be independent of frequency over the range of frequencies considered in this article, but a multiplying factor *F* is included in this term to accommodate the increase in resistance with increasing frequency (*1*).

These lead to the following expressions:

$$R = F \cdot 8\eta \cdot \frac{12}{\pi a^4},\ L = \left(\frac{\varrho}{\pi a^2}\right)\left(\frac{12P}{14\cdot 7}\right),\ C = \frac{12\pi a^2}{\gamma P}$$

where F = 1·2 for ¼ in. outside diameter lines and 1·4 for ⅜ in. outside diameter lines

a = radius, in.
η = viscosity of air, lb–s/in².
ϱ = density of air, lb s²/in⁴.
γ = ratio of specific heats, here assumed 1·1
P = absolute pressure, lb/in².

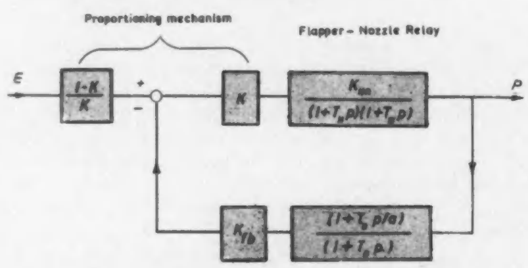
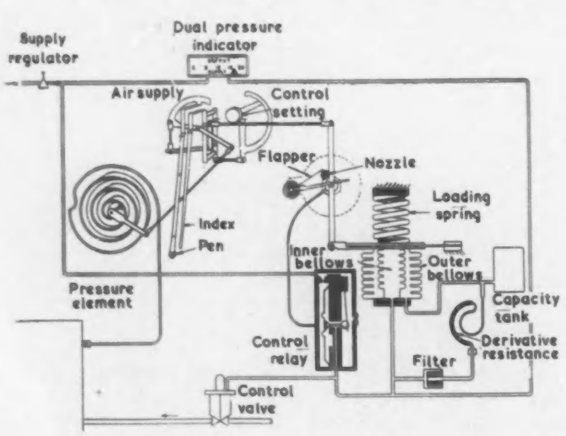


Fig. 2 Block schematic of proportional-with-derivative controller
K = proportional gain
K_{NR} = output change (lb/in²)/flapper travel (in.)
K_{fb} = feedback movement (in.)/output change (lb/in²)
K_L = loop gain = $K\ K_{NR}\ K_{fb}$
a = derivative gain-limiting coefficient

Practical investigations into the frequency responses of varying line lengths and loads (the latter ranging from pneumatic receiver elements up to large diaphragm motors) clearly show that these systems are non-minimum phase, and that the load itself has very little effect on the phase lag when the latter exceeds 180°. The conclusion may be drawn that the line presents the greater contribution to the lag of the whole system as the frequency is increased, and that the load must be of the order of a diaphragm motor assembly for the phase lags at low frequency to be substantially independent of the line length. The responses also exhibit underdamped characteristics with short line lengths even with large loads.

It is proposed to examine in this article how the effect of a given line and load upon a transmitter and a controller frequency response may be determined.

Fig. 1 Schematic of proportional-with-derivative controller



Source resistance

All transmission lines are fed by a relay or booster that has a finite resistance to flow which can be conveniently expressed in units of (lb/in²) / (ft³/s). This resistance is not necessarily linear or constant, since it can be shown to vary with both direction and magnitude and mean level of the disturbance, and also with the character of the load, depending upon whether this is lumped or distributed.

The effect of this source resistance R_s is to cause an additional term to be applied to equation (1) of the form

$$F_{j\omega} = [1 + R_s(C_0 + Cl)j\omega(1 - j\omega RlC_0)]^{-1}$$

where the overall transfer function becomes $G'_{j\omega} = G_{j\omega} \cdot F_{j\omega}$.

For long line lengths, irrespective of the load, $F_{j\omega}$ is approximately given by

$$F_{j\omega} = [1 + R_sClj\omega]^{-1}$$

and in the range of frequencies being considered, it is sufficient to use only the expression

$$F_{j\omega} = [1 + R_sC_0j\omega]^{-1}$$

for large loads and short lines.

This last condition will apply primarily to directly mounted controllers or volume boosters on a valve diaphragm motor, or to valve positioners where the line length is 2 ft at the most.

Since a common figure for the relay resistance is of the order of $2{\cdot}5 \times 10^{-2}$ (lb/in²) / (ft³/s) it can be shown that, when short line lengths and large loads are being considered, the correction term will be a relatively high frequency one, and will not materially affect the response in the frequency domain for small disturbances; but it will provide a correction term which has to be applied when any step disturbances are considered (*1*). When long line lengths and any load are considered, this correction term is of so high a frequency order that it is negligible for both sinusoidal and step disturbances.

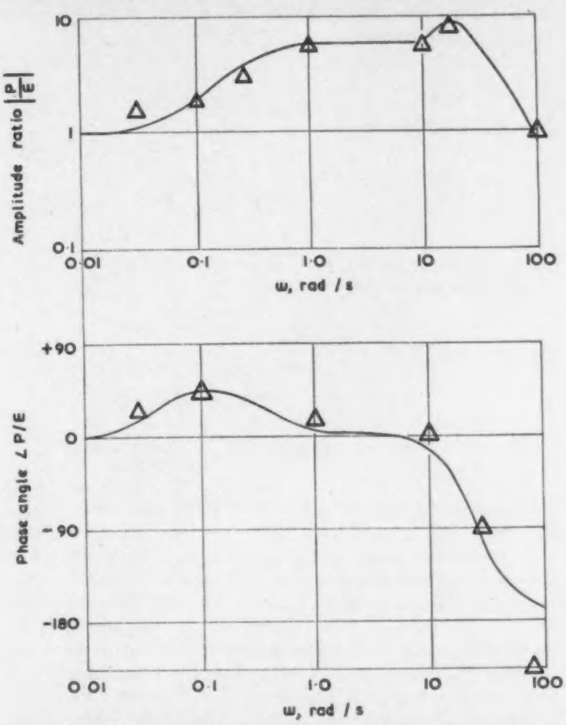


Fig. 3 Frequency response of unloaded proportional-with-derivative controller

Δ = practical results; input ± 0·1 lb/in²; 100 pc proportional bandwidth; 20 sec derivative

Line and load constants

Tables 1 and 2 list the terms b_1, b_2 and b_3 for various combinations of line and load lengths of both ¼ in. and ⅜ in. outside diameter lines, at a mean pressure level of 9 lb/in² gauge and 60° F ambient temperature. Table 3 lists the line constants used in formulating Tables 1 and 2. All units are consistent, in pound-second-inch units, per foot run of line length, and all pressures are absolute.

In determining the effective impedance of a spring-loaded diaphragm motor, the spring constant has to be taken into consideration and the effective capacitance of the diaphragm assembly is

$$\left(C_0 + \frac{Ax}{12}\right)$$

where C_0 is the pneumatic capacitance at 9 lb/in², A is the effective cross-sectional area of the diaphragm at the same position, and x is the total travel produced for a pressure change of 12 lb/in². This leads to the expression

$$\left(V_0 + \frac{AxP}{12}\right)$$

as the effective volume at a pressure P, in terms of the normal volume V_0 at the position corresponding to pressure P.

Practical applications

A schematic of a typical proportional-with-derivative controller is shown in Fig. 1 and its equivalent block diagram in Fig. 2. This controller is of the type which has a stabilizing capacitance across the derivative resistance. Reduction of the block diagram gives the following expression as the ratio of output pressure to error signal when there is no load on the controller, except for the volume of the pressure measuring device.

$$\frac{P}{\varepsilon} = \frac{\text{output}}{\text{error}} = (1-K)K_{NR} \cdot \frac{\dfrac{1}{(1+T_Np)(1+T_Rp)}}{1+K_L \cdot \dfrac{(1+T_dp/a)}{(1+T_dp)(1+T_Np)(1+T_Rp)}}$$

where T_d is the derivative time-constant.

Therefore

$$\frac{P}{\varepsilon} \simeq K' \cdot \left[\frac{1+T_dp}{1+T_dp/a'}\right] \cdot \frac{1}{1 + 2\zeta\dfrac{p}{\omega_N} + \dfrac{p^2}{\omega_N^2}} \quad . \; . \; (2)$$

where

$$\left.\begin{aligned} K' &= \frac{(1-K)K_{NR}}{1+K_L} \\ a' &= \left(\frac{1+K_L}{1+\dfrac{K_L}{a}}\right) \\ \zeta &= \frac{T_N+T_R}{2\sqrt{[T_NT_R(1+K_L)]}} \\ \omega_N &= \sqrt{\left(\frac{1+K_L}{T_NT_R}\right)} \end{aligned}\right\} \quad . \; . \; . \; (3)$$

At 100 pc proportional bandwidth

$$K_L = 63$$

Independent examinations yield $T_N = 1{\cdot}25$ sec, $T_R = 0{\cdot}04$ sec.

thus $\zeta = 0{\cdot}5$ and $\omega_N = 25$rad/s.

and $a' = 4{\cdot}7$ when $a = 5$.

It will be seen that equation 2 is the transfer function of a proportional-with-derivative controller and that the actual value of the stabilizing transfer function in the derivative network has been modified in the complete system. There is also a second-order term determined by the nozzle time-constant in the relay and the relay load itself, here assumed to be simply the impedance of the measuring device, which is, therefore, effectively a lumped load.

Fig. 3 illustrates the good agreement between theory and practice of the analysis of such a controller where the nozzle time-constant is 1·25 sec, the relay time-constant is 0·04 sec, and the loop gain is 63 for a proportional band of 100 pc. The

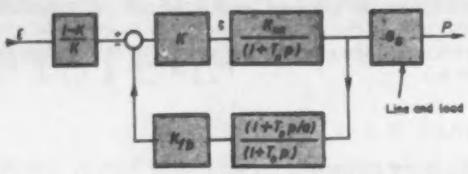


Fig. 4 Block schematic of proportional-with-derivative controller with line and load

factor a' is found to be 4·7 as opposed to the normal steady-state value of 5. The derivative time-constant is 20 sec.

Figs. 4 and 5 illustrate the same controller with a load of 100 ft of ⅜ in. line to a diaphragm motor of effective volume 94 in^3 at mid-stroke, and for good measure the effect of altering the load to an effective volume of 665 in^3 is also illustrated. This shows the effect of these loads for a given line length upon the controller performance, with the derivative time-constant at 6 sec. Under loaded conditions the relay time-constant is ignored.

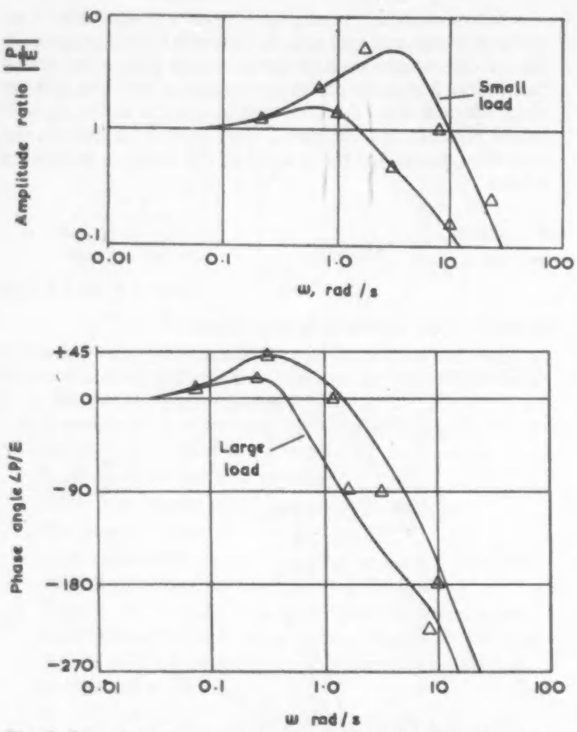


Fig. 5 Frequency response of proportional-with-derivative controller to small and large loads using 100 ft × ⅜ in. line.
Δ = practical results; input ± 0·1 lb/in^2; 100 pc proportional bandwidth; 6 sec derivative.

Reducing the block diagram of Fig. 4 yields

$$\frac{P}{\varepsilon} = (1-K)K_{NR}\cdot\frac{\dfrac{1}{1+T_N p}}{1+K_L\cdot\dfrac{(1+T_d p/a)}{(1+T_d p)(1+T_N p)}}\times\frac{1}{(1+b_1 p+b_2 p^2+b_3 p^3+\ldots)}$$

$$= K'\cdot\frac{1+T_d p}{1+2\zeta_1\dfrac{p}{\omega_1}+\dfrac{p^2}{\omega_1^2}}\cdot\frac{1}{(1+b_1 p+b_2 p^2+b_3 p^3+\ldots)} \quad \ldots (4)$$

where

$$\left.\begin{aligned}\omega_1 &= \sqrt{\left(\frac{1+K_L}{T_d T_N}\right)}\\ \text{and}\quad \zeta_1 &= \frac{T_d\left(1+\dfrac{K_L}{a}\right)+T_N}{2\sqrt{[(1+K_L)\,T_N T_d]}}\end{aligned}\right\} \quad \ldots (5)$$

If $T_d = 6$ sec, $T_N = 1{\cdot}25$ sec, and $K_L = 63$, then $\omega_1 = 3$ rad/s and $\zeta_1 = 1{\cdot}9$. Since in this case $\zeta_1 > 1$, the second-order term may be expressed as a product of two exponential lags such that

$$T = \frac{1}{\omega_1}\left[\zeta_1 \pm \sqrt{(\zeta_1^2-1)}\right] \quad \ldots (6)$$

This gives $T_1 = 1{\cdot}17$ sec and $T_2 = 0{\cdot}09$ sec.

Fig. 6 illustrates the block diagram of an unloaded differential-pressure transmitter, and Fig. 7 compares the theoretical with the actual unloaded response. The block diagram of this transmitter is essentially the same as the proportional-with-derivative controller, except that the feedback network has no frequency term, and the loop gain has a different value. Loading this transmitter with a line to a pneumatic receiver alters the block diagram in the same way as with the proportional-with-derivative controller, and results in the following overall transfer function

$$\frac{P}{M} = \frac{\text{output}}{\text{measurement}} = (1-K)K_{NR}\cdot\frac{\dfrac{1}{(1+T_N p)(1+T_R p)}}{1+K_L\cdot\dfrac{1}{(1+T_N p)(1+T_R p)}}$$

$$= K'\cdot\frac{1}{1+2\zeta\dfrac{p}{\omega_N}+\dfrac{p^2}{\omega_N^2}} \quad \ldots (7)$$

where ζ and ω_N are the same as in equation (3).

When the transmitter is loaded

$$\frac{P}{M} = (1-K)K_{NR}\cdot\frac{\left(\dfrac{1}{1+T_N p}\right)}{1+K_L\cdot\left(\dfrac{1}{1+T_N p}\right)}\cdot\frac{1}{(1+b_1 p+b_2 p^2+b_3 p^3+\ldots)}$$

$$= K'\cdot\left[\frac{1}{1+T_N p/(1+K_L)}\right]\cdot\frac{1}{(1+b_1 p+b_2 p^2+b_3 p^3+\ldots)} \quad \ldots (8)$$

This is also compared in Fig. 7 for 100 ft and 200 ft of ¼ in. line, and it will be seen again that the agreement is satisfactory.

Particular emphasis can be placed upon the knowledge of the effects of transmission lines on measuring elements, since one is in a better position to assess the true deviation of the measured variable in a control loop, if one can eliminate the transmitter and line characteristics from the overall response. Undesirable resonances can occur with short line lengths and it is worthy of note that in applying force-balance differential-pressure transmitters on close-coupled flow loops, these resonances can cause instability. A knowledge of the dynamics of the transmission lines here enables one to assess the potentialities of the system in regard to stability.

Discussion of results

Inspection of Tables 1 and 2 shows that for all line lengths above 100 ft using conventional valve diaphragm operators the use of larger bore tubing has every advantage, since the increased bore is more effective in reducing the resistance to

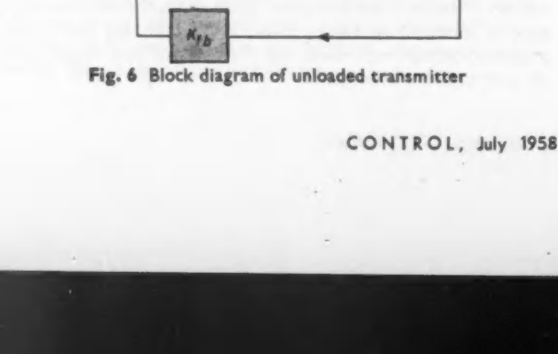


Fig. 6 Block diagram of unloaded transmitter

flow (and thus improving the response) than the increase in capacitance due to this bore is in causing reduced performance in the frequency domain.

This can be seen by comparing the relative values of b_1 for any line length and load in the different sizes of tubing, since this is the dominant term in the determination of phase lag at normal process frequencies. Further, this improvement is in no way impaired by the source resistance of conventional relays with air flow deliveries in the region of 1 std ft³/min.

A similar analysis to that performed on the force-balance transmitter may be carried out on valve positioners, the only difference being that the relay load now involves the diaphragm motor assembly. A discussion is contained in reference (*1*) on the effects of a valve positioner in a control loop. Also in this reference is an alternative method of presenting these line and load constants, whereby the polynomial is rearranged into a distance velocity-lag and either an exponential lag or a second-order underdamped system. This method has the advantage of simplifying the investigation of the effects of these loads on loop performance with the aid of an analogue computer. The author feels, however, that the treatment afforded above is adequate for individual cases.

Summary

The methods of analysis given in this article enable one to assess the dynamic performance of any transmission line and load for lengths up to 1000 ft, using ⅜ in. and ¼ in. outside diameter tubing.

Further, a quantitative determination can be made of when the instrument characteristics become important in the overall response, and also of how the line and load affect the performance of a controller with given frequency settings. It is then but a short step to determine the new derivative time-constant

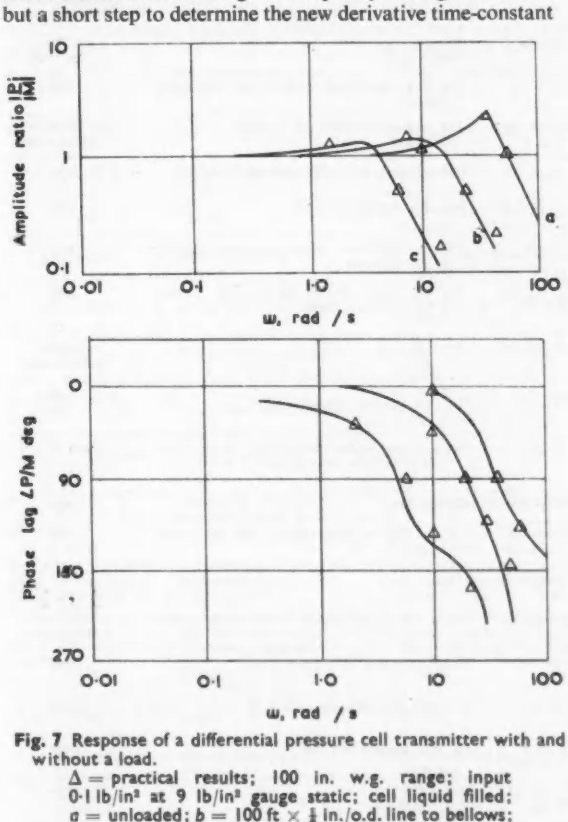


Fig. 7 Response of a differential pressure cell transmitter with and without a load.
Δ = practical results; 100 in. w.g. range; input 0·1 lb/in² at 9 lb/in² gauge static; cell liquid filled; *a* = unloaded; *b* = 100 ft × ¼ in./o.d. line to bellows; *c* = 200 ft × ¼ in./o.d. line to bellows

required to restore the phase advance with a given line length for a large load to that obtained with the same line length and a smaller load.

It has been found sufficient over the ranges of frequency considered to use only the terms b_1 and b_2 in the transmission line equation.

When equations 2, 4 and 8 are considered, it will be seen that application of the step response to a small disturbance presents complications in the manipulation of the transfer functions. It is felt that a sufficient knowledge of the frequency response behaviour is a satisfactory quantitative method of assessing the relative behaviour of different systems.

ACKNOWLEDGMENTS
The author is indebted to the management of Foxboro-Yoxall Ltd for permission to publish this article, and to many of his colleagues for confirmation of the validity of some of the conclusions drawn, in the searching light of practical experience.

REFERENCES
1. Samson, J. E.: 'Dynamic Characteristics of Pneumatic Transmission' (to be published in the *Trans Soc. Instrum. Technol.* in 1958)
2. Hochschild, E. F.: 'Dynamic study of an experimental pneumatic process-pressure transmitter' Amer. Soc. Mech. Engrs Paper 57–IRD–7

TABLE 1 *Constants for 0·25 in. × 0·188 in. tubing*

Load, in³	Length, ft	b_1	b_2	b_3
2	10	$1·61 \times 10^{-3}$	$1·05 \times 10^{-4}$	$5·06 \times 10^{-10}$
	50	$2·32 \times 10^{-2}$	$1·57 \times 10^{-3}$	$3·06 \times 10^{-6}$
	100	$8·68 \times 10^{-2}$	$6·90 \times 10^{-3}$	$1·95 \times 10^{-4}$
	200	0·33	$3·95 \times 10^{-2}$	$1·17 \times 10^{-2}$
	500	2·01	0·80	2·12
	1000	7·84	14·2	160
94	10	$4·35 \times 10^{-2}$	$2·84 \times 10^{-3}$	$1·80 \times 10^{-6}$
	50	0·23	$1·70 \times 10^{-2}$	$5·80 \times 10^{-5}$
	100	0·51	$4·50 \times 10^{-2}$	$1·93 \times 10^{-3}$
	200	1·20	0·18	$6·80 \times 10^{-2}$
	500	4·10	2·32	7·70
	1000	12·0	21·0	334
310	10	0·14	$9·50 \times 10^{-3}$	$6·03 \times 10^{-8}$
	50	0·74	$5·30 \times 10^{-2}$	$1·90 \times 10^{-4}$
	100	1·52	0·14	$6·20 \times 10^{-3}$
	200	3·20	0·53	0·21
	500	9·20	5·90	21·0
	1000	22·0	48·0	760
665	10	0·31	C·02	$1·30 \times 10^{-7}$
	50	1·60	0·11	$4·10 \times 10^{-4}$
	100	3·20	0·29	$1·32 \times 10^{-2}$
	200	6·50	1·10	0·43
	500	17·5	12·0	43·1
	1000	39·0	92·1	1460

TABLE 2 *Constants for 0·375 in. × 0·305 in. tubing*

Load, in³	Length, ft	b_1	b_2	b_3
2	10	$5·05 \times 10^{-4}$	$7·40 \times 10^{-5}$	$2·72 \times 10^{-11}$
	50	$9·40 \times 10^{-3}$	$1·38 \times 10^{-3}$	$2·82 \times 10^{-7}$
	100	$3·62 \times 10^{-2}$	$5·50 \times 10^{-3}$	$1·54 \times 10^{-5}$
	200	0·14	$2·40 \times 10^{-2}$	$9·50 \times 10^{-4}$
	500	0·87	0·25	0·23
	1000	3·50	2·52	14·4
94	10	$7·70 \times 10^{-3}$	$1·10 \times 10^{-3}$	$6·30 \times 10^{-10}$
	50	$4·60 \times 10^{-2}$	$6·80 \times 10^{-3}$	$2·21 \times 10^{-6}$
	100	0·11	$1·70 \times 10^{-2}$	$7·61 \times 10^{-5}$
	200	0·29	$5·20 \times 10^{-2}$	$1·96 \times 10^{-3}$
	500	1·24	0·41	0·44
	1000	4·10	3·40	19·7
310	10	$2·53 \times 10^{-2}$	$3·60 \times 10^{-3}$	$2·11 \times 10^{-9}$
	50	0·13	$1·93 \times 10^{-2}$	$6·62 \times 10^{-6}$
	100	0·28	$4·31 \times 10^{-2}$	$2·20 \times 10^{-4}$
	200	0·63	0·12	$3·24 \times 10^{-2}$
	500	2·11	0·77	2·51
	1000	5·90	5·71	78·1
665	10	$5·21 \times 10^{-2}$	$7·50 \times 10^{-3}$	$4·31 \times 10^{-9}$
	50	0·27	$3·95 \times 10^{-2}$	$1·33 \times 10^{-5}$
	100	0·55	$8·62 \times 10^{-2}$	$2·14 \times 10^{-3}$
	200	1·22	0·22	$6·82 \times 10^{-2}$
	500	3·44	1·41	6·01
	1000	8·63	8·31	192

TABLE 3 *Line constants 9 lb/in² gauge 60° F ($\gamma = 1·1$)*

LINE	R	L	C	RC	L/R
¼ in. × 0·188 in.	$1·22 \times 10^{-3}$	$8·01 \times 10^{-6}$	$1·27 \times 10^{-3}$	$1·55 \times 10^{-6}$	$6·55 \times 10^{-3}$
⅜ in. × 0·305 in.	$2·05 \times 10^{-4}$	$3·01 \times 10^{-5}$	$3·36 \times 10^{-3}$	$6·91 \times 10^{-7}$	0·145

1 CONTROL SURVEY

HYDRAULIC AND

This technical survey is the first of a series on components that could be employed in a control system. It is intended that succeeding surveys will include electrical, electronic, hydraulic and pneumatic equipment. The information in the surveys will inevitably be brief but we hope that each will prove a convenient and representative guide, without necessarily including every manufacturer. In this survey the following

MANUFACTURER	DESCRIPTION	BORE, IN.	TYPE OF CYLINDER	MAX. OPERATING PRESSURE, LB/IN.²
Airtech Ltd *Haddenham, Bucks*	hydraulic pneumatic	2–6 1–4	SA, DA, telescopic, through-rod (pneumatic)	2000 300
Baldwin Instrument Co Ltd *Brooklands Works, Dartford, Kent*	hydraulic pneumatic	1½, 2½, 3 4½, 6, 8	DA, single and double rod	250 150
H. S. Cattermole & Co (Hydraulics) Ltd *Astwood Bank, Redditch, Worcs*	hydraulic	1⅛–6	single and double acting; double acting telescopic	2200
Consolidated Pneumatic Tool Co Ltd 232 *Dawes Road, London, SW6*	pneumatic	2½, 3, 4, 5, 6, 7, 8, 9	SA, DA cushioning available for ⩾ 4 in. bore	
Electro-Hydraulics Ltd *Liverpool Road, Warrington, Lancs*	hydraulic pneumatic	0·5–8	telescopic. SA. DA. Three volume	up to 200 pneumatic. Up to 4000 hydraulic (special 8000 hydraulic)
Exactor Ltd *Exactor Works, Church Way, Edgware, Middx*	hydraulic	2⅛, 2½, 4½, 5 4, 5	SA DA	1500 750, 1000
Globe Pneumatic Eng Co Ltd *Harold Hill, Romford, Essex*	pneumatic	4–12 std	SA, DA, cushioned, double rod, automatic, specials	120
Keelavite Rotary Pumps and Motors Ltd *Allesley, Coventry*	hydraulic	1, 1½, 2, 2½, 4, 5, 6	DA, double rod end; SA to order	1 in. bore 1000 others 1500
George Kent Ltd *Luton, Bedfordshire*	pneumatic	3, 5½, 7, 10	force-balance type position control unit	150
Hydraulics and Pneumatics Ltd *Villiers Street, Wolverhampton*	hydraulic or pneumatic	1½, 2, 3, 4, 6	DA, SA, double-end rod	200
Lang Pneumatic Ltd *Birmingham Road, Wolverhampton*	pneumatic	⅜–20	SA/DA/cushioned; double impulse; tandem; double end rod	150
Lockheed Industrial Hydraulic Div., Automotive Products Co Ltd *Liverpool* 19	hydraulic (also with special seals pneumatic)	⅞, 1¼, 1⅝, 2¼, 3, 4, 5½	DA (std), SA or double end to order. *Autoloc* in 1¼ and 1⅝ in. bores	3000
W. H. Marley & Co Ltd 105 *High Road, New Southgate, N11*	hydraulic	2½, 3, 3⅞, 4⅞, 11	DA	10,000 continuous
Martonair Ltd *Parkshot, Richmond, Surrey*	hydraulic pneumatic	1⅛–12	SA. DA, tandem, double-ended	250 150
Maxam Div The Climax Rock Drill and Engineering Works Ltd *Redruth, Cornwall*	pneumatic or hydraulic (low pressure)	⅞–12	SA ⅞ in. and under. Others DA: above 1⅛ in. with or without cushioning	tested to 250
John Mills & Co (Llanidloes) Ltd *Llanidloes, Mont*	hydraulic	Up to 15	SA and DA	3360
The Plessey Co Ltd *Cheney Manor, Swindon, Wilts*	hydraulic	9 bores std 1–3½	SA and DA std displacement type: telescopic	2000
Pneuspeed Ltd 127 *Edinburgh Avenue, Slough, Bucks*	pneumatic	⅞, 1½, 2½, 3, 4, 6, 8	DA	100
Power Jacks Ltd *Maylands Avenue, Hemel Hempstead, Herts*	hydraulic	1·42, 1·79, 2⅛, 2⅝	SA extension, DA and retraction-single stroke	3000 max 1500 normal
Smiths Jacking Systems Ltd *Jackall Works, Edgware Road, NW2*	hydraulic	1·06–4·0	Single, true and differential DA	2000
Spenborough Engineering Co Ltd *Union Road, Heckmondwike, Yorks*	hydraulic	1½–7	SA telescopic: DA and pull types	2000
Stein Atkinson Vickers Hydraulics Ltd 60 *Buckingham Palace Road, SW1*	hydraulic	1–6 ACR 2, 3, 4 std	SA, DA, double-end rod	2000
Telehoist Ltd *Manor Road, Cheltenham*	hydraulic	2½, 2⅞, 3⅝, 4½, 5½, 6½	SA or DA	2000
Weston Works (B'ham) Ltd *Greet, Birmingham, 11*	hydraulic	1½–6	telescopic, SA, DA, pull rams	2000
Westover Hydraulics *River Road, Barking, Essex*	hydraulic	6	SA, DA, double-end rod	2500

The following manufacturers do not provide a standard range but construct equipment to a customer's specific requirements British Messier Ltd, S. G. Brown Ltd, Chamberlain Industries Ltd, Dowty Group

PNEUMATIC CYLINDERS

abbreviations have been used: SA=single acting. DA=double acting. std=standard. ACR=according to customer's requirements. The number of different proprietary cylinders is very large and the survey does not attempt to indicate all the different types and sizes in detail. Thus the entries are intended, not as a catalogue, but as a guide to the extent and the possible uses of a manufacturer's products.

STROKE	SEALS	MOUNTINGS	REMARKS AND SPECIAL FEATURES
	twinset and chevron	ACR	tailor-made rams for all purposes
normal maximum 7 ft	synthetic rubber	foot; front and rear flange; front, centre and rear trunnion	hard chrome plated and polished bore and piston rod
up to 7½ ft	O and U rings	foot, base, flange, trunnion	cushioning fitted at either end ACR
	synthetic rubber	trunnion, flange, foot	pendant hoists; a wide variety of special purpose rams
½-60 in.	Electro-Hydraulics proprietary seals	clevis, trunnion, spherical, etc.	rams manufactured incorporating internal mechanical locks in extended or closed positions or both with switch indication if required; damping valves; provision for mounting sequence valves, swivel connexions, etc.
up to 3½, 4½, 6, 6 ft up to 8, 2½ in.		rear flange and pivot for 2½ in. bore; others rear flange or pivot	
½ in.-10 ft		all types	mainly steel construction. Foundry and steel mills equipment a speciality
up to 6, 40, 40, 70, 80, 100, 130 in.		rear foot flange, front flange, clevis trunnion, double flange	cylinders ACR. Chromium plated rods; with or without special damping; special rods available
6, 12, 24, 36 in.	leather or plastic	trunnion or end	automatic device for locking position on air failure and providing remote control
various	O rings	foot (L bracket), rear and front flange, clevis tongue and bracket, threaded head	cushioning available on all models; manufactured of non-corrosive materials
¼ in.-12 ft	synthetic rubber	foot, rear flange, front flange, trunnion (front, rear, centre), neck, base, double-neck	a range of 8 interchangeable mountings with 11 standard strokes is available in bore sizes 1½, 2½ and 3 in.
wide range	spring urged high duty	flange (front, rear), clevis (pivot pin), or bare cylinder ACR	*Autoloc* have position locking device. Heads 'cirkeyed' to barrels
24 in.	Ronald Trist neoprene-canvas	threaded head in conjunction with nosecap locking ring	SA and DA control units, pumps, etc available for 7000 lb/in² continuous rating
up to 17½ ft	O and U rings heat resisting as specials	foot, front flange, rear flange, screwed nose, tie-rod, trunnion (rear, front, centre), front yoke, clevis (front, rear)	fully cushioned
any practicable length	synthetic rubber	ACR	wide range of standard rams; honed bores, compact, clean design
36 in.	composite piston rings, twinseal gland packing.	front flange (foot also in lower capacities)	any variations considered
ACR		generally flange, clevis and trunnion	various special purpose rams available
1½—4 in. bore up to 24 in. Others up to 12 in.	synthetic rubber U type seals	foot, rear flange, front flange, trunnion, screwed nose	
ACR	synthetic rubber and bonded asbestos	extension jacks pivot mounted; DA and retraction-pivot at bottom threaded head	
ACR	chevron and Sealtrist	pin joints	honed bore tube; cleaner gland fitted to prevent foreign matter entering jack
ACR	wiper	various	hard chrome plated piston rods; honed bores; cushioning and restrictions available
up to 6 ft	chevron packings	foot, flange (front and rear), clevis (pivot), trunnion	cushioning if required, at either or both ends
12-42 in.		pivot	
in general up to 6 ft	wiper	clevis, spherical, fork, trunnion	hard chrome piston rods; all rams fitted phosphor-bronze bearings
24 in. max		front flange, foot, threaded head	bores and rams hard chromed, ground and lapped

Ltd, Hymatic Engineering Co Ltd, Integral Ltd, Leeds Engineering and Hydraulic Co Ltd, Oswald & Ridgway Ltd, Sperry Gyroscope Co Ltd and Tangyes Ltd. For addresses, see the *Buyers' Guide* section.

Two Cambridge lecturers explain basic ideas on automation control and discuss its evolution

What is control engineering?

1-AUTOMATION AND CONTROL

by **C. M. BURRELL,** M.A., B.Sc., A.M.I.E.E., & **J. K. LUBBOCK,** M.A., B.Sc.

Lecturers in Department of Engineering, Cambridge University

This is the first article of a series being written by Mr Burrell and Mr Lubbock, who instruct engineers taking postgraduate courses in control systems engineering. These one-year courses were pioneered by the well-known control engineer, Mr J. F. Coales, with whom the authors work at Cambridge.

In the articles the authors will set out some of the ideas covered in the early stages of the Cambridge course. The subject is approached from its exemplification in present-day 'automation', and its historical development is outlined. The article is quite general, and will be intelligible to the man with no knowledge of control systems. But there will be few who can read it without finding points that jog their minds. It is interesting too that the authors use the word 'automation' in a sense considerably wider than is customary—to include, for example, speed regulation, guided missiles, and ship stabilization.

In later articles the authors will develop a mathematical theory of control, the emphasis being on systems rather than on particular instruments, amplifiers, motors or other apparatus.

Automation

Automatic machinery

The popular appeal to the imagination of the word 'automation' is the probable reason for the changed and broadened meaning which it has acquired since its introduction by Del Harde of the Ford Motor Co in 1947. He defined it as 'the automatic handling of parts between progressive production processes'.

Today, full automation implies the automatic accomplishment of an entire series of tasks or operations on some object. Automation of a process may, of course, be accomplished in whole or in part. The object upon which the operations are carried out may be material, or it may be abstract. (Strictly, any process of any kind must involve matter and therefore material, but the looser classification is readily understood and is more useful.)

An automatic profiling machine will accept a mild steel sheet and automatically cut from this sheet a piece of specified size and shape, which it then ejects. In this example the object is material—the mild steel cut to a given shape.

An example of an automatic machine operating on an abstract object is a voltage regulator, designed to accept an energy supply of widely varying voltage, and to supply a substantially constant voltage to a varying load. Regulation is carried out on the basis of comparing the actual load voltage with a desired load voltage and taking appropriate automatic action. In this case the inputs are 'raw' energy and information in the form of the desired voltage (fed in by a human). The output is energy.

As a final example, consider an electronic computer working out weekly wages and income tax. The machine is given information about the employees, i.e. tax code number, rates of pay including overtime rates, hours worked during the week, bonuses etc, and produces a weekly pay chit. In this example the 'abstract' object is information fed to the machine, which processes it to give an output that is again information.

These examples indicate that the 'object' upon which automatic operations are carried out may be classified as:

1 Material 2 Energy 3 Information

Whatever the classification of the object upon which the operations are carried out, the complete machine will always involve the two other quantities in the above classification.

Although it is a commonplace that any machine is made of materials, and consumes energy when it operates, the fact that information is invariably required for automatic operation is not usually so clearly recognized. A more general outlook is to define the input and output as information only; then material and energy objects in the system become merely 'carriers' of information.

In the examples already mentioned, information is involved as follows:

Profiling machine. Information is required about the shape to be cut, which may be presented directly as a shape (template), e.g. 'copy milling', or as instructions written on punched tape, etc. This machine may be considered to process this information by translation from digital form (if the information is on punched tape) into a shape and by transference from one material carrier onto another.

Voltage regulator. The information as to the desired output voltage is injected on a low-power carrier and imposed upon a raw high-power energy supply. Energy is the information carrier throughout.

Tax computer. The information input concerns the employees; a set of numbers, and operations to be carried out on these numbers. The input and output carriers may be material (e.g. punched tape or typed sheet) but the internal carrier is almost entirely energy.

Feedback control

The required information invariably originates from a human being, and must be stored by the machine so that it can operate automatically, i.e. without human intervention.

The storage may be permanent as when information is 'built into' the machine in its design, an example being a voltage regulator where the desired value of output voltage may be obtained from a neon tube, or the storage may be semi-permanent as when the information is punched on paper tape.

In addition to the above direct instructions, it is frequently necessary that the machine be able to inform itself of changing circumstances so that it can take action appropriate to producing the required operation in spite of the changing circumstances. The simplest way in which this can be done is for the machine to detect small, but tolerable, changes in its output and take appropriate corrective action whatever the cause of the change.

For example, the voltage regulator operates by constantly measuring its actual output, comparing this with the desired output, and taking appropriate action. Thus, if its output is higher than required, it reduces it, and vice versa; and within the designed range, the cause of the error, e.g. change in input voltage, change of load current, or ageing of components, is of no consequence.

This process may properly be regarded as continuous inspection of the finished product, continuous action being taken to ensure that the product quality is always within the required limits. Such a system is called a *feedback control system.* The features (not all essential but usually present) of an automatic system may be listed as:

Inputs for information, energy and often material.

Storage for information, and often energy and material.

Operator (e.g. mechanical or electrochemical, but not human) which may involve positioning, assembly, transport, computation, machining and other processes producing transformation of the object.

Controller to control the operator.

Inspection element to provide the controller with information as to the 'quality' of the output object.

Output.

The complete machine or process may be a very complex sequence, and information, energy and material may be injected at various stages of the sequence.

The human being

Regarded as machinelike, we see that human activity involves almost every conceivable form of automation, including chemical plant, automatic positioning, balancing and transport, automatic temperature and liquid content control, and so on.

The senses, such as sight and hearing, inspect the situation; the brain and spinal cord carry out computations on the information thus gathered and then control the muscles and other parts of the body to produce the desired result.

The operation of driving a car is a good example here. It involves the decision to traverse a given route, and storage of the route in the brain. Also stored, of course, is the action appropriate to starting, stopping, turning, reversing, avoiding collision, etc. Inspection involves continuous examination of direction of travel relative to that of the road, observation of the position and speed of the traffic, observation of steepness of gradient and the car's response to it, etc.

The operation of changing gear on a hill is particularly interesting, since automatic gear-changing devices (automatic transmission) are now commonly available. Any driver approaching a hill inspects it as a whole, and decides the pattern of speed and gear ratio which he will follow in advance. For example, a hump-backed bridge may well be negotiated without changing gear, simply by speeding up on approaching it, so that momentum carries the car over the bridge at a proper speed. The automatic transmission, on the other hand, can do no such comprehensive inspection and prediction—it simply changes down when the required engine torque exceeds a given value.

The human being is, in fact, extremely versatile, and in this respect is superior to any single inanimate device so far constructed. Purely human activity is, however, restricted by severe limitations on:

1. Available power, force, torque, etc. Human performance is easily and often exceeded by that of machines.

2. Accuracy and range (both in kind and in magnitude) of inspection element.

3. Accuracy of computation.

4. Speed of operation, even where the forces etc involved are well attainable.

5. Effective lack of some devices, e.g. hard sharp edges for cutting purposes, etc.

The evolution of automation

Automation in its broadest sense began when man first used a simple tool to extend his range of operations. Here we might perhaps choose the use of a rock as a means of killing, or stunning, an animal. It is of some interest that even some birds are tool users, e.g. the Darwin's finch, which is found in the Galapagos islands, is woodpecker-like in that its bill is specially adapted for chiselling out insects from the bark of trees. Unlike the woodpecker, however, it has no long tongue with which to fish insects out from crannies and cracks. Instead, it picks up a twig or pine needle, and pokes this into the crack so as to flush the insect from cover.

The evolution of automation may be classified as follows:

1. Use of hand tools evolving into fairly elaborate human- or animal-powered machines.

2. Utilization of sources of power, e.g. wind, water, fossil fuels, and recently atomic energy.

3. Coupling of power source and machines.

Roughly speaking, the above three stages constituted the first Industrial Revolution, culminating in accurate, high-

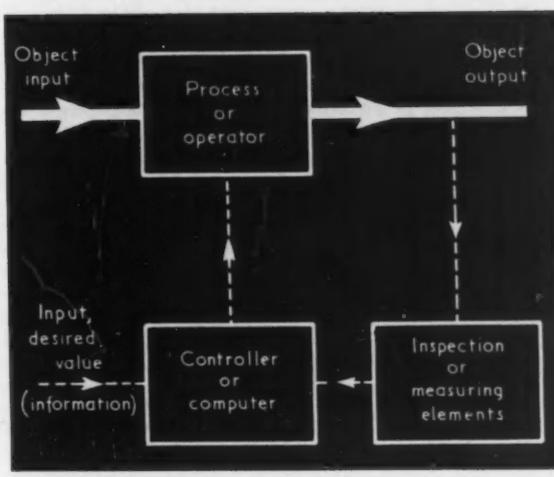


Fig. 1 Essential components of a closed-loop system

powered machines. These however relied almost entirely on man as the inspecting and controlling or programming element.

At first gradually, with completely mechanical systems, and recently much more rapidly with the advent of electronics, the fourth stage (historically overlapping the third) has been and still is occurring; here the inspecting, computing and controlling functions previously exercised directly by humans have been increasingly delegated to inanimate devices invented for these purposes.

We may envisage several further stages, as machines approach man in range and versatility. One stage may be called the construction of machines which learn. We distinguish learning from simple storage of information by saying that learning involves purposive experiment, deduction and further experiment, aimed at finding a sequence of operations

which will achieve a desired output object from a given input object. The sequence must then be stored for further use under similar circumstances.

Taking an artificially simple example, we envisage a mechanical mouse running along a tunnel which has a number of dead-end offshoots. The mouse has been instructed to traverse the tunnel into the daylight at the far end. At each junction, it has an even chance of picking the right route, and when it turns into a dead end, it must recognize this, retreat from the dead end and proceed along the alternative path. Evidently the mouse could be arranged to make many such experiments,

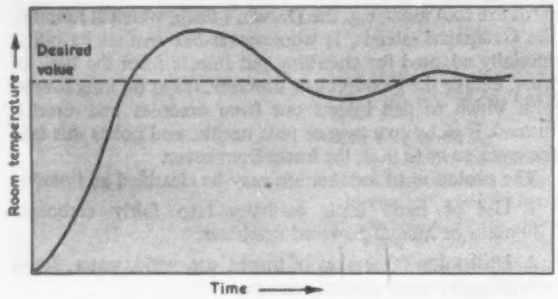


Fig. 2

and to record the results so that on the next trip it made no mistake and completed its task much more quickly than before.

Obviously there is little point in making a machine learn to perform a task where the required sequence of operations is completely known; but a machine which can learn can solve problems where we can supply only the input and output objects, and not the detailed sequence of intervening operations.

Control systems

It has been explained that the controller is the unit which activates the operator in the performance of a task. The controller, operator and inspection element may together form a closed loop and thus constitute a feedback system; or on the other hand the control may be obtained by means of an open loop, with no feedback.

Consider the open-loop control of a domestic central heating system. The temperature of the water circulating in the radiators is controlled by varying the position of the damper in the boiler flue. This may be done manually by the householder, who opens the damper more in cold weather than in hot; and some refinement may be obtained by measuring temperature (outside the house) by a thermometer instead of relying on feelings of cold or warmth. The householder is then the controller.

To make the system automatic the outdoor thermometer can be arranged, by an electrical or mechanical linkage, to control the damper position. Since the indoor temperature cannot affect either the outside thermometer or the damper position, there is no feedback and the system is automatic but open loop. The system can be improved by measuring wind velocity as well as outside temperature and controlling the damper by a quantity dependent on both wind and temperature.

Now the thermometer can be inside the house instead of outside, and it can still control the damper opening; so that when the room temperature exceeds a desired value the damper closes and when room temperature falls below the desired value the damper opens. There is then a feedback loop since the following quantities depend on each other, in turn; room temperature—thermometer reading—damper aperture—rate of supply of heat to radiator—room temperature. Thus the system forms a closed loop (Fig. 1) and consequently it is liable to hunt, or oscillate. This characteristic feature is explained as follows: suppose the room temperature falls, the water begins to get warmer, and in turn the air temperature increases. Unfortunately the rise in room temperature lags behind the rise in water temperature, which in turn lags behind the damper setting. When the room temperature reaches the desired value the damper stops opening, but because of the lags in heat transfer, the room temperature continues to rise, producing an overshoot in the controlled quantity. The damper closes and the room temperature falls, but it may now undershoot the desired value (Fig. 2). A hunting movement about the desired value can thus occur through lags in a closed loop.

In a well-damped system the hunting should become insignificant after a few overshoots. In a badly damped system the oscillation may persist for some time. It may even increase indefinitely, and a system in which this occurs is called unstable and is useless as a control system.

Whilst this closed-loop control has the disadvantage that it tends to produce hunting, it has the great advantage that it automatically resets the damper to compensate for a wide variety of changes in surrounding conditions; e.g. wind force, outside temperature, calorific value of fuel. There is no need to measure these quantities separately; instead it measures the actual thing to be controlled, and automatically combats any disturbance which affects room temperature.

An open-loop system has the advantage that it cannot be unstable, and the disadvantage that its complexity increases with the number of disturbances to be combated. The further disadvantage of inflexibility may be illustrated by the fact that an open-loop system would completely fail to respond to the opening of a door or window, since it has no means of measuring change of indoor temperature. A closed-loop system, however, would soon detect the fall in temperature and take appropriate action.

Summary

Any automatic process involves the use of open- or closed-loop control systems, or both together; thus automation could be defined as the progressive application of the science of control. In taking this view, the authors have attempted in this article to trace the history of automation as an evolutionary process arising from man's desire to supplement his own physical and mental abilities. Various stages of evolution have been listed, and these lead to speculation on further human attributes which could be advantageously imitated in inanimate machines; one such quality which is just beginning to be used and which may have far-reaching application is the ability to learn by purposive experiment.

Examples demonstrate that an automatic process may involve storage, operation, control and inspection. The object involved may be material or abstract (i.e. material energy and information). Information is required for the operation of any process, and in automation this information invariably originates from a human being.

When the controller, operator and inspection elements together form a closed loop, the system constitutes a feedback or closed-loop system. Although open-loop systems are more common in industrial applications, feedback systems possess unique attractive features as well as inherent disadvantages (e.g. hunting), which together will form the subject of future articles in this series. Only two systems, which obviously involve feedback, have been described so far (i.e. the voltage regulator and the domestic heating system) but feedback theory is applicable to all manner of control systems. A few examples are ship stabilization, missile guidance, aircraft autopilots, and chemical plant.

REFERENCES

Grabbe, Eugene M.: 'Automation in Business and Industry' (Wiley, 1958).

Ashby, W. Ross: 'Design for a Brain' (Chapman & Hall).

Walter, W. Grey: 'An Imitation of Life', published in *Automatic Control* a *Scientific American* book (Bell, 1957).

COMPUTER CONTROL OF MACHINE TOOLS

the first part of an article describing the Ferranti system

by **D. T. N. WILLIAMSON,**

Head of Machine Tool Control Department, Ferranti Ltd, Edinburgh

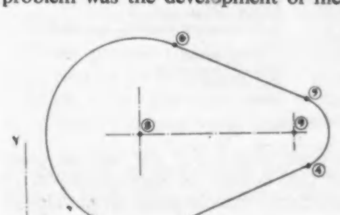
The Ferranti true-path system of numerical control of machine tools has been one of the most successful so far developed in either Great Britain or the USA. In this first part of an article describing the system for the user of machine tools the author explains the philosophy behind it, outlines the equipment it involves, and shows how the system operates in practice. For the benefit of those unfamiliar with numerical control of machine tools, it should be pointed out that the pros and cons of the parabolic interpolator and of true-path control systems for machine tools are not yet resolved. Not everyone will thus agree with all the author's opinions, but few would deny that the development of the Ferranti system, which is still continuing, has been of great importance for the improved productivity of British industrial machine shops.

In the second part of the article, to be published next month, Mr Williamson will discuss the requirements of numerical control for the machine tools themselves, measuring devices used on the tools, and the economics of the Ferranti system in relation to hand control.

I. BACKGROUND

The development of the Ferranti system of machine tool control began in 1951 with the study of the methods of manufacture of small quantities of metal components. The plant at Edinburgh, in which this development has been carried out, is devoted to the manufacture of many types of precision instruments, each type of which is made only in small batches, but may contain hundreds of different machined components. The fluctuating demand for these components created severe labour problems, since a fluctuating labour force could not be realized in the prevailing conditions of supply and demand for skilled machinists; it was to alleviate this situation that the development was originally started.

It seemed probable that machine tools could be controlled with high accuracy, provided that the position of the slides could be measured, and that the speed of control possible could increase the speed of manufacture by ten or twenty times, but it was clear from the start that the biggest single problem was the development of methods of data-handling which would allow complex articles to be specified simply and easily by the sort of people who made these objects conventionally.



Nº	X Co-ord	Y Co-ord	Z Co-ord
1	026000	010000	020000
2	036000	010000	"
3	050240	010780	"
4	088430	029890	"
5	088430	050110	"
6	050240	069220	"
7	042400	010000	"
8	036000	040000	"
9	083400	040000	"

Fig. 1 Co-ordinated engineering drawing of a simple cam

The development of a special type of computer to achieve this has been long and expensive, involving the creation of new computer techniques in order to obtain computing speeds which make the process economic. The system of manufacture which has resulted from this work has, in the author's opinion, many advantages over other numerical control systems, which have come into being in the intervening time. The philosophy underlying the system has been that data-handling will always be the greatest problem and that methods of doing it can constantly be improved. Control and measurement, on the other hand, have now reached a stage, with the development of new measuring systems and servomechanisms, where significant improvements in performance are unlikely and indeed unnecessary. The Ferranti system is, therefore, based on a central computing service, in which improvements in data-handling are continually being made; this central service supplies magnetic tapes to the users of control equipment which contains only servomechanisms, and which, though unlikely to be improved in performance, will become simpler and cheaper as development continues. The use of new techniques in the computer has enabled true curves to be generated without using approximations or interpolations for curves of second degree. Interpolation facilities are available if required for higher-order or unknown curves.

People frequently ask whether, if the system were being redesigned in the light of the knowledge now acquired, its basis would be changed. The answer is 'definitely no', because the present basis is the only way known in which the benefits of numerical control can be applied to single components and can be brought to the small user without saddling him with high equipment costs; at the same time it ensures that his equipment has a very low obsolescence rate and can carry out the most difficult work.

The conception of programming for numerical control has hitherto been based on the specification of lines of movement of the cutter. This will steadily change to the simple specification of whole areas of movement of the cutter, which will greatly ease the planning problems for dies, moulds and other multi-dimensional shapes, but which will not involve any alteration of existing control equipment. This advance can come about only by the use of more complex computing equipment.

At the other end of the scale there are many special-purpose applications for which continuous-path control methods are not necessarily the best solution. They *may* be—for example, in a factory which has a number of continuous-path-controlled machines and its own computer in operation, the use of continuous-path techniques in order to position

the table of a machine carrying out relatively simple operations is entirely sensible since this will be the cheapest piece of additional equipment, especially if the work involves any appreciable amount of programming of a kind that could be done by a computer.

There is, however, a wide application for machines which are tailored to suit a particular type of operation; for example, machining castings for gas and steam turbine casings and castings for machine tools and other capital equipment, as in many industries there are products which change quite appreciably in dimensions but remain more or less constant in form and require only simple machining such as spot facing, boring and drilling. These machines can be considered intermediate between general-purpose continuous-path-controlled milling machines and special-purpose transfer-type machines which are built to make one article and then discarded. The control system for such machines must, like the machines, be tailored to suit the job, but the basic requirements of high reliability and self-checking remain paramount.

Computer-controlled manufacture has shown up the need for similar methods of inspection, which at present can take up to one hundred times as long as manufacture. Two categories of inspection are desirable, spot inspection and continuous inspection (*1*). Spot inspection involves the programming of a light, accurate machine with an inspection head to move to predetermined points and record any error from true position. Continuous inspection is desirable for jobs where the whole surface is important, e.g. aerofoils, turbine blades and templates. Spot inspection machines can take the form of punched-tape-controlled positioners which are simple and accurate. But a continuous inspection machine would necessarily be magnetic-tape controlled and follow a true path rather than an interpolated one, because the necessity to keep the tracking errors low would involve great difficulty in feeding information into the interpolating system.

2. THE SYSTEM FROM THE USER'S VIEWPOINT

All numerical control systems can be divided into two sections—data-handling and control. The data-handling facility determines the field of application of the system, what work it can do and what it cannot do; the control engineering determines the speed and accuracy of execution of the work. Both together determine the capabilities of the system. For example, a system which has good data-handling (i.e. computational) facilities allied to poor control engineering would theoretically be able to tackle a wide range of work; but the range would, in practice, be limited by low measurement accuracy or slow response of the control servomechanisms, which could mean that the actual machining would take longer than necessary and only wide-tolerance work could be handled. Another system, with poor data-handling facilities (e.g. hand-computation) allied to good control engineering, is suitable for only a limited range of work, mainly two-dimensional profiling, unless the number to be produced of each component is large enough to justify the cost of efficient data-handling. In the right conditions this second system will be capable of good work.

A third system, with poor data-handling and poor control engineering, would have limited range, speed and accuracy, but would still be suitable for rough template production and similar applications. A system with good data-handling facilities and good control engineering would be capable of a wide range of work at any degree of precision, with the highest and most economical production rates.

2.1 The units of the Ferranti system

As outlined in Section 1, the data-handling of the Ferranti system is based on a central computer service, which is continually being expanded, and the control engineering is based on a range of servomechanisms of very high performance and on measuring systems of great accuracy. The design accent in the computer is on providing the widest possible data-handling facilities and a high operating speed, substantially irrespective of capital cost; in the control unit it is on achieving the desired speed and accuracy at a low cost, with high reliability, fail-safe operation and simple maintenance.

In this way, the user has the best of both worlds; the capital equipment which he buys is simple and flexible, it has low initial and maintenance costs, and it will not become obsolescent quickly; the user can extend its applications at no additional cost other than the normal computer service charge.

The system thus entails the following equipment:

a. The *teleprinter equipment*, used to encode the planning data in a form (punched tape) suitable for

b. The *computer*, which carries out all the complex calculations involved in converting the raw data into control information for the servomechanisms and records this on magnetic tape, which is used in

c. The *control unit*, containing the required number of digital servomechanisms, which lock, to the magnetic tape commands, the slides of

d. The *machine tool*, equipped with measuring systems and servomotors, which performs the final machining operation.

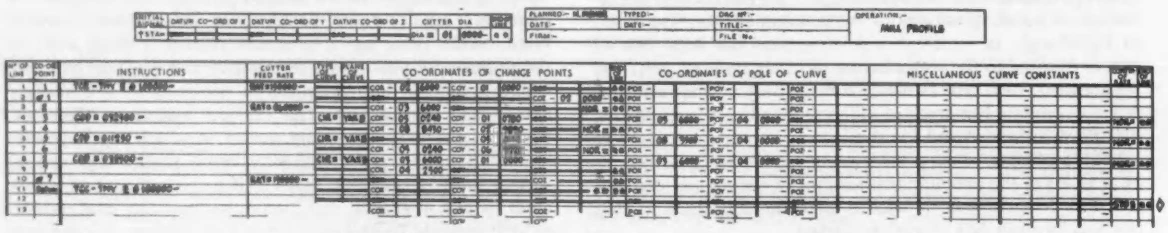


Fig. 2 The Ferranti planning sheet used for the cam in Fig. 1

CODE	COMPUTER INSTRUCTION	CODE	COMPUTER INSTRUCTION	CODE	COMPUTER INSTRUCTION
XAY≡	Select *XY* plane curve clockwise	COX–	*X*	TCL–	Tool compensation (tool centre to left of profile)
YAX≡	,, *XY* ,, ,, anticlockwise	COY–	Set in *Y* co-ordinate of final point of section	TCR–	Tool compensation (tool centre to right of profile)
YAZ≡	,, *YZ* ,, ,, clockwise	COZ–	*Z*	TCC–	Tool centre cut
ZAY≡	,, *YZ* ,, ,, anticlockwise	POX–	*X*	DIA≡	Tool diameter
ZAX≡	,, *ZX* ,, ,, clockwise	POY–	,, ,, *Y* co-ordinate of pole or curve	RAT=	Feed rate
XAZ≡	,, *ZX* ,, ,, anticlockwise	POZ–	*Z*	NOR=	Switch off rate control
CIR=	Set up circle	GRD=		STA=	Start computer magnetic tape deck
MIS≡	Miscellaneous curve (general second degree, or specifically ellipse, hyperbola, or parabola)	COD=	Approximate radius of circle	STO=	Stop
DAX– DAY– DAZ–	Co-ordinates of datum (machine tool setting point)	TNX≡ TNY≡ TNZ≡	Tangent normal (for tool diameter compensation)	+	Clear all stores
		INT=	Commence interpolation	* *	End of instruction
		END=	End interpolation	◇	End of tape
				θ	Minus

The –, = and ≡ signs are purely of significance for automatic digital checking.

2.2 Preparation of data

2.2.1 Design and drawing stage

The design of components has not yet been influenced by numerically controlled manufacturing methods, except with integral spars for aircraft*. This is so because these methods have been introduced only recently and their potentialities are not well understood. During the next five years, as experience grows, it is likely that the design of components intended for numerically controlled manufacture will change considerably—and with some components profoundly. The ability to produce circles of any radius, second-degree or interpolated curves to high accuracy and complex surfaces which can be easily specified, can greatly simplify the design and specification of many types of component.

For a number of components, e.g. turbine blades and fluid propellers, design as at present carried out will probably cease, and the magnetic tapes for manufacturing the components will be produced by a computer directly from the relevant thermodynamic, aerodynamic or hydrodynamic equations and given boundary conditions.

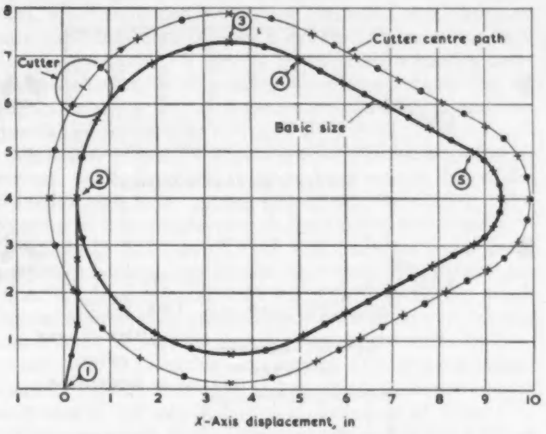


Fig. 3 Intermediate drawing, showing position of co-ordinate points necessary for producing the cam of Fig. 1 by an interpolating system. The values of co-ordinates are not given

The crosses represent major points and the dots minor points
1. Programme zero point
2. Point marking the start and finish of the work
3. Point of maximum Y ordinate
4. Tangent point at end of large circle and start of straight line
5. Tangent point at end of straight line and start of small circle

Under present conditions, however, the drawing dimensions require to be specified as Cartesian co-ordinates from a datum point. The time taken to do this is about the same as to specify conventional dimensions, probably varying by $\pm$ 10 pc with the type of component. If a drawing has to be dimensioned conventionally and also with co-ordinates, this adds up to 50 pc to the dimensioning time.

2.2.2 Programme planning

This is the process for putting information into the control system and is not to be confused with any methods planning which may be required, as for conventional manufacture. Programme planning consists of writing down the required machining sequences in code form, and the Ferranti system aims at keeping this information as simple as possible so that an average machinist can be trained to do this in a few hours.

The process consists of abstracting, from the co-ordinate drawing, change points to define the curves of the component in the sequence in which it is proposed to cut them. A change point is in fact a point where one type of curve intersects another. For example, two points are required to define a straight line—the positions of the beginning and the end, irrespective of the length; and three points are necessary to define a circular arc—the positions of the beginning and the end of the arc, and the centre of the circle. For other conic sections, additional simple gradient information is required. Where the curve is higher than second order, interpolation is used so that a smooth curve defined by a number of points can be cut. The facilities for straight lines, circles, conic sections and interpolation are called up by the planner at will, simply by writing a code word such as CIR, ELL, HYP, INT, etc. Where no code word is written, the co-ordinates are treated as defining a straight line.

The computer requires only the dimensions of the part and the diameter of the cutter in order to provide full cutter-diameter compensation, but obviously this information must be given unambiguously and simple codes have been devised to ensure this.

The information required to be written on the programme sheet consists of

a. *Machine setting point.* If the cutter starting point differs from the datum point on the co-ordinate drawing, the difference between these values must be inserted in a space provided on the planning sheet. Thereafter the computer will take care of this.

b. *Cutter diameter.*

X		*Y*		
MINOR	MAJOR	MINOR	MAJOR	NOTES
	Align machine code			
00175	00350	00660	01320	
00350	00350	01980	02640	Run in ordinates
00350	00350	03320	04000	Initial cutting point
00460	00785	04842	05625	
01302	01975	06298	06815	Section A
02758	03600	07140	07250	
04331	05024	07166	06922	Section B
05501	05979	06683	06444	
06456	06934	06205	05966	Section D
07411	07889	05727	05488	
08366	08843	05249	05011	
09103	09304	04836	04596	Section E
09431	09475	04311	04000	
09431	09304	03689	03404	Section E¹
09103	08843	03164	02989	
08366	07889	02751	02512	
07411	06934	02273	02034	
06456	05979	01795	01556	Section D¹
05501	05024	01317	01078	
04431	03600	00834	00750	Section B¹
02758	01975	00860	01185	Section A¹
01302	00785	01702	02375	
00460	00350	03158	04000	
00350	00350	04100	04200	
00350	00350	04200	04200	Run out
	Stop code			

Fig. 4 Table of programmed ordinates for the cam of Fig. 1, required by an interpolating system.

c. *Feed rate.* The rate at which the material is to be removed must be settled and entered on the sheet. This and the cutter diameter can be changed at any time during the programme if required.

* These were formerly fabricated from sheet, angle and T-sections riveted together to form a rigid structure, but are now cut from a solid block by pocketing, leaving the stiffening members integral with the back surface, about 95 pc of the original metal being removed in the process. This gives a much stronger, cheaper and more aesthetically pleasing structure, which has been made possible by the parallel development of stretched, distortion-free light-alloy plate and automatic machine tool control.

d. *Compensation sense.* Instruction codes are provided whereby the planner can define on which side of the contour he requires the cutter to travel either to the right or to the left, or whether he wishes the cutter centre to travel along the contour. Additional simple instructions are necessary when the cutter is initially positioned at the start of a continuous machining sequence. This information defines the displacement of the cutter centre from the start of the track but does not have to be repeated in a continuous machining sequence unless the cutter is removed from the work.

e. *Co-ordinates of change points.* These must be abstracted from the co-ordinate drawing and entered in the columns provided.

f. *Type of curve.* The code instruction defining the type of curve to be generated between two change points is entered in the same line as the change points.

g. *Plane of curve.* This specifies the plane in which the curve is to be generated, e.g. X and Y, X and Z, etc.

h. *Co-ordinates of pole of curve.* The centre of a circle is entered in this column, as also are the poles of other conics as required.

Fig. 1 shows a drawing of a simple cam and Fig. 2 the specimen Ferranti planning sheet for it. It will be noted that points 1 and 7 on the co-ordinate drawing are 'dummy' points. These are used in order to ensure that no cutter dwell marks are left on the work, by approaching and retracting the cutter tangentially. Figs. 3 and 4 are included to allow a comparison in the amount of work necessary between planning for the Ferranti control system and for a typical interpolating system. The two figures show the equivalent drawing and planning sheet necessary in such a system (*2*) for the component of Figs. 1 and 2.

In addition to specifying many more points on the planning sheet of the interpolating system, the planner must calculate the co-ordinates of each of these points, since they would not appear on an engineering drawing. An additional offset point must also be calculated for each of the previous points, because interpolating systems require that the track of the centre of the cutter be programmed; 'cutter compensation', if available, is confined to small adjustments intended to cover the change of size when a cutter is reground. (These additional points are not shown on the planning sheet of Fig. 4.) The problem is increased as the size of the component increases, for a machine of a given resolution, since the spacing of the co-ordinate points has to be more or less constant, and hence more are necessary for a larger object.

2.2.3 Encoding

The planning sheet (for the Ferranti system) is encoded on punched tape in order that it may be read by the computer. This is accomplished by copy-typing the planning sheet line by line on a teleprinter, which produces a correctly coded paper tape and simultaneously a red copy of the planning sheet that can be compared with the original. The tape is normally fed back into a reader in the teleprinter, which produces another identical tape and a black copy of the planning sheet. By comparing the versions of the planning sheet, errors can be quickly located if they occur.

2.3 The computer

The calculation work necessary to achieve simple programming is at present done by a special-purpose computer. This computer is essentially a digital differential analyser and has the ability to define the cutter-compensated forms of straight lines and of any second-degree curve at any angle to the axes, and to make a cutter-compensated parabolic interpolation between specified points, such that the curve gradients entering and leaving these points are identical. Controlled by the punched-tape replica of the planning sheet, the computer calculates the cutter track and records this on magnetic tape at very high speed (at present eight times the speed of machining), at the same time drawing a track of the centre of the cutter on a sheet of paper. Although the automatic checks ensure that the computer will record correct information, planning errors can, of course, occur and the drawing helps considerably in locating these.

As mentioned before, the computer facilities are being greatly extended and ultimately will be able to cover a very wide range of work. At this stage mention might be made of alternative methods of preparing the magnetic tapes for the control system. Fig. 5 shows four arrangements, each of which has certain advantages in different circumstances. Arrangement 1, i.e. a special-purpose computer as at present used, is ideally suited to the running of a computer service, but it implies a large capital investment which would not be justified unless it could be fairly fully occupied. In Arrangement 2 a differential analyser or curve generator is coupled to a general-purpose computer. This can carry out all the work which the special-purpose computer can do but it is

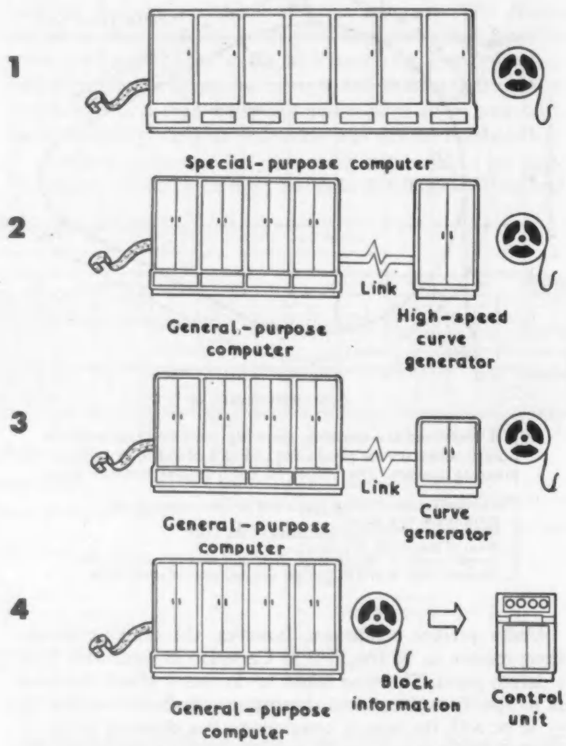


Fig. 5 Alternative computer arrangements which can be used to prepare magnetic control tapes

1. *Special-purpose computer.* Fastest, cheapest to operate. Used only as a service to feed many machines
2. *General-purpose computer and high-speed curve generator.* Can be the equivalent of (1) but somewhat more expensive to operate.
3. *General-purpose computer and curve generator.* Low capital cost solution where large tape-making capacity is not required. Can supply several machines under normal conditions.
4. *General-purpose computer and control unit with integral curve generator.* Suitable where one machine only is to be used and no computer service for magnetic control tapes is available.

somewhat more expensive to use and may be slower. It has, however, the advantage that the general-purpose computer is available for other work, and the method is, therefore, appropriate to organizations which could use a general-purpose computer for scientific or business purposes. Arrangement 3 is similar to 2 but the curve generator records tape

more slowly; this reduces the capital cost and is suitable for feeding a few control units. In Arrangement 4 the curve generator is included with each machine tool, but, as mentioned before, this is necessarily expensive, and it is to be recommended only where one or two machines are to be used and there is no possibility of access to a computer service.

2.4 The computer service

Only the very simplest two-dimensional numerical control problems can be solved economically without a computer, and then only if the number of each component to be made is greater, say, than ten. As the field where numerical control is the cheapest and best way to do a given job grows—and it is already quite large—it becomes clearer and clearer that larger and faster computers are required to handle the wide variations in data and types of problem. To attempt to compute such data by hand methods would be fabulously expensive.

Where numerical control systems are installed in large works, a self-contained installation consisting of a computer and a number of control units is entirely economic and very convenient, especially if use can be made of an existing computer installation, or if a newly installed computer can be used for scientific and commercial calculations in addition to machine-tool control.

The largest volume of application of numerical control is, however, not to be found in large organizations, but in the countless small firms spread throughout the country who specialize in the manufacture or finishing of components. It is precisely in this type of work that the most complicated problems requiring the largest data-handling facilities are found. It is also essential that the capital investment which these small firms must make to enjoy the benefits of numerical control must be kept to rock-bottom. In the author's view, the only way to meet this requirement is to have centralized computer facilities available, and to supply as simple control equipment as will satisfy the needs of the type of work.

It may be noted that a computer service for the Ferranti system has been established in Edinburgh; it is at present supplying tapes for controlled machines distributed throughout Britain, and it will shortly be supplemented by another computer, based on London, capable of dealing with most complex multi-dimensional work. The current practice is that the user sends a roll of punched tape, representing the encoded planning sheet, which has been prepared by his planning staff, along with the black copy of the planning sheet prepared automatically by his teleprinter, these being accompanied by an order form, embodying any additional information. Upon receipt at Edinburgh, the punched tape is processed through the computer and the resulting magnetic tape or tapes together with a drawing of the cutter track, prepared automatically by the computer, are dispatched to the user the same day. Because of the very complete checking system employed in the computer, errors are infrequent and those which occur are mainly errors in planning. These are usually within the scope of the computer service planning engineer to correct; if necessary a telephone call is made to the customer's planning engineer.

2.5 The control unit

As previously explained, the control unit for a continuous-path controlled machine is kept as simple as possible. It contains a magnetic tape reader, which in essence is an instrument similar to the tape recorders now in general use, except that it is made much more robustly in order to be able to stand up to continuous industrial use, and all its mechanical brakes and movements are solenoid operated, so that it may be remotely controlled. This feature makes it easy to ensure that the mechanism is foolproof and will not break tapes owing to variations in the speed of movement of the release mechanisms, a fault which is common to the simpler forms of tape mechanism. The magnetic reading head is suitable for reading four in-line tracks simultaneously.

The function of the equipment in the control unit is to produce, in conjunction with the motors, gearboxes and measuring systems fitted to the machine tool, movements of the machine tool slides in synchronism with the commands from the magnetic tape. There are many different ways in which this might be achieved. The Ferranti system aims at being able to use the method most suitable for any given application and to assemble the necessary equipment from standardized units, in order that the accuracy and cost of the control equipment can be suited to the application.

The present standardized units use thermionic valve techniques and are based on a synchronous digital system of switching logic identical to that used in the computer. This has great flexibility and has proved to give very great day-to-day reliability. Transistor techniques will be used in the future, and there will be other developments. It cannot be expected, however, that such developments will improve significantly the accuracy of control—this is already higher than the cutting accuracy of available machines. Nor is there much room for improvement in the reliability, although simpler systems with fewer components will probably be inherently less liable to breakdown. However, it is likely that the same accuracy and speed of operation will be attainable with greater simplicity and at lower cost, without sacrificing standards of reliability and self-checking, which are the most important features of industrial control equipment.

2.5.1 Electric servomechanism

Naturally the design of the control unit is influenced considerably by the type of servomechanism used. Two main types have been developed. The first was an electric servomechanism using compact 3-phase 400 c/s induction motors which were specially developed to give a peak output of 0·7 b.h.p. at a speed of 10 500 r.p.m., and which are capable of accelerating at 100 000 r.p.m./s (10 400 rad/s^2). The electrical control of this motor can be by means of a high-speed magnetic amplifier or by transistors, and the resulting servomechanism has acceleration and bandwidth which the author believes is unequalled by any other electric servo of similar power rating. The power rating has been found to be adequate for the heaviest cuts in steel which can be taken on a No. 4 size milling machine without damage to the machine. It has also been used to give feed rates up to 150 in./min on a large (24 ft by 6 ft; slide weight 4 tons) milling machine for cutting light alloy, and it has proved most reliable in operation because it has no commutator or moving connections. Fig. 6 shows a block diagram of the technique used in one type of control unit with this servomechanism. The control channel pulses are read from the tape, synchronized, sorted into positive and negative commands and fed simultaneously to a binary store and a ratemeter, which produces a voltage proportional to the command velocity. This drives the servomechanism consisting of mixing network, amplifier, motor and tachometer at a speed within 2 pc of its correct value. Displacement feedback from the grating measuring system is also fed to the binary store and compared with the command pulses, the difference producing an appropriate signal, which is added to the velocity signal in the mixing network to reduce the possible 2 pc error to one digit. This system has proved very flexible and easy to apply to closed loops which are not ideal.

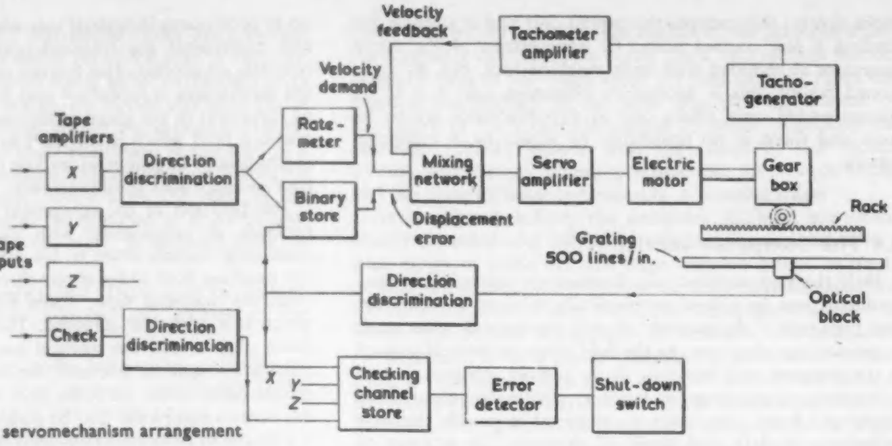


Fig. 6 Block diagram of the servomechanism arrangement

2.5.2 Hydraulic servomechanism

If machine tool slideways and transmissions were designed according to the best-known principles, there would only rarely be a need for servomechanisms more powerful than the one just described. Unfortunately this is not, at present, the case, and a considerable amount of machine tool control consists of adaptations of existing machines. Where these have conventional slideways and are larger than the No 4 size, higher peak power must be supplied in order to overcome the frictional resistance reliably. This power could be obtained in an electrical servomechanism by increasing the size of the servomotor and amplifier, but only at the expense of lowering the performance, because the inertia increases faster than the torque.

A much better performance can be obtained in a high-powered servomechanism if it is made hydraulic, and, accordingly, a range of hydraulic servomechanisms from 2 b.h.p. to 20 b.h.p. has been developed, which can power the largest machine tools, and could be extended to 50 b.h.p. if exceedingly heavy equipment had to be controlled. The hydraulic servomechanism consists essentially of an electromechanical control valve, usually a two-stage device in order to achieve a high electrical sensitivity, manifolded to a hydraulic motor, the aim being to keep the entrapped volume of oil at a minimum so that the stiffness can be high. Hydraulic power at 2000 lb/in^2 is supplied by means of an automatic off-loading pump and if necessary the impedance of the oil supply lines is kept low by siting a hydraulic accumulator of suitable capacity near to the motor and valve assembly. Such a system with suitable components is capable of a bandwidth in excess of 100 c/s, which is more than adequate for machine tool control.

In certain applications it has been found possible to use hydraulic rams as actuators, but this is not generally possible because the stiffness of a ram is only one-hundredth of that of an equivalent column of steel (e.g. a lead screw), owing to the low bulk modulus of oil. Nevertheless, the use of a ram is attractive and various hybrid devices are under development in an attempt to combine the simplicity of a ram with the high performance of a rotating hydraulic motor.

2.5.3 Additional equipment

In addition to the equipment directly concerned with moving the slides of the machine tool, the control unit has to contain equipment which checks on the accuracy of these movements and facilitates the smooth running of the controlled machine tool in a system of production. For example, it is desirable for the slides of the machine tool to be returnable to a known datum position, either automatically from tape, or manually by pressing a button. This means that the work can be set in a predetermined position on the table by means of a sub-table, the position of which is registered by dowels. This moves the problem of setting the cutter with respect to the work to an earlier stage remote from the machine tool and so greatly eases the turn-round of work and increases the utilization of the machine tool, which is necessary for the sound economic operation of such a piece of capital equipment.

Facilities are also provided at will for the remote control, from information recorded on the tape, of auxiliary machine functions such as spindle speed, coolant, oil mist, cutter change and so on. Machine tools so equipped and designed to facilitate easy chip removal can become almost fully automatic, apart from work handling.

The checking system which is employed in the control console ensures that the work cannot be damaged by any fault which may develop in the equipment or its control tape. This is important because it is the only means whereby a user can gain complete confidence in complex equipment of this type. The method of checking used is to record, on a fourth track on the magnetic tape, a pulse train which, derived in the computer, consists of the sum of the pulses on the three slide control tracks divided by four. This division factor is used in order to ensure that the maximum rate recorded on the check track does not exceed the rate on the control tracks and also to ensure that, if information is lost from the control and check tracks simultaneously, it still shows as an error. In operation the pulse outputs from the measuring systems on the machine tool are added and divided by four and continuously compared with the total from the check track, as shown in Fig. 6. If there is any discrepancy, the machine tool is automatically shut down.

Facilities are also usually required, particularly on large machines, for remote manual control of the slide movements in order to ease cutter change, setting, etc.

Finally, the control console contains built-in marginal test equipment, which enables the control channels to be interchanged or paralleled and the voltages on the screens of the valves to be lowered section by section, so that any potentially faulty unit can be located by a short test carried out each morning, using the built-in cathode ray tube for observation. Special tapes are provided to enable this to be done, and to test the servomechanisms for acceleration and power output. The servomechanisms must pass a test to ensure that the complete slide and transmission system is capable of eight times the maximum acceleration which can be demanded by the control tape, this being limited automatically by the computer as a safeguard. No possibility can therefore exist of overshoots or other errors.

To be concluded next month

REFERENCES

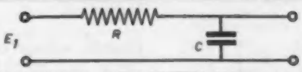
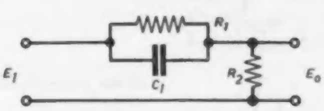
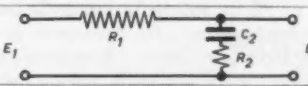
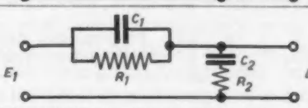
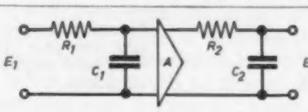
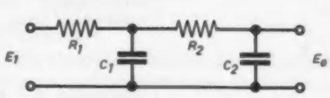
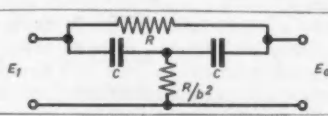
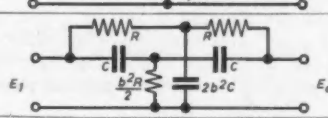
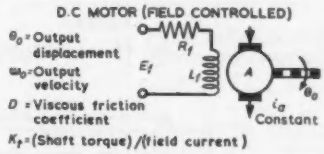
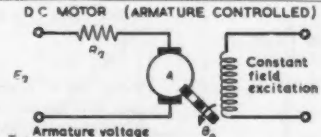
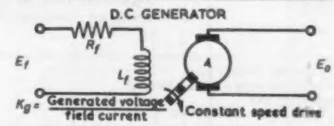
1. Elton, H. J.: 'Three-Dimensional Tape-Controlled Inspection', Conference on Technology of Manufacture 1958 (Inst. Mech. Engrs)
2. Farmer, P. J.: 'Programming' *Aircraft Production*, 1957, **19**, pp 344–355

DATA SHEET—1

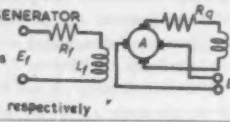
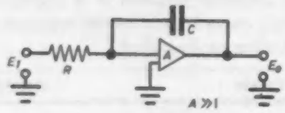
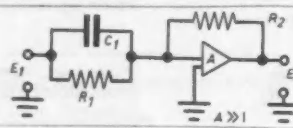
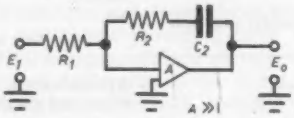
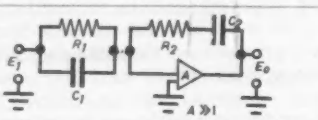
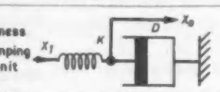
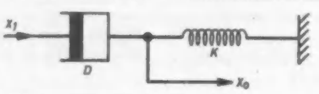
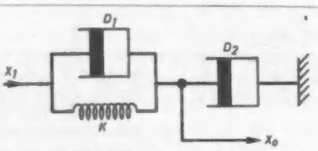
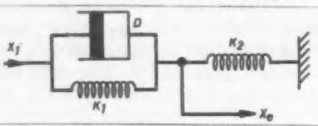
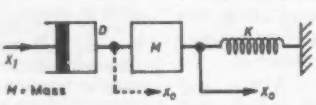
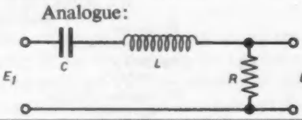
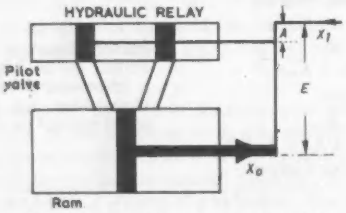
Basic transfer functions

by **N. G. MEADOWS**
Wimbledon Technical College

This table lists some of the more common elements of servo systems, excluding process controllers and pneumatic systems. The effects of non-linearities are ignored; e.g. in elements 10, 11 and 12, torque/field-current, generated e.m.f./excitation and B/H relationship are all assumed to be linear. In element 22 the velocity of the ram piston is assumed to be directly proportional to the displacement of the valve stem, while in elements 13 to 16 high amplifier gain values are indicated. In the electrical networks it is assumed that the input voltage is fed from a source of zero internal impedance and that there is no impedance loading on the output.

	ELEMENT	TRANSFER FUNCTION	REMARKS
1		$\frac{E_o}{E_i} = \frac{1}{1 + pCR}$	Phase lag network.
2		$\frac{E_o}{E_i} = A\frac{1 + pC_1R_1}{1 + pAC_1R_1}$ where $A = \frac{R_2}{R_1 + R_2}$, the d.c. transfer function	Phase lead. Approximately gives proportional and error rate term in output: used for servo stabilization.
3		$\frac{E_o}{E_i} = \frac{1 + pC_2R_2}{1 + pC_2[R_1 + R_2]}$	Approximately gives proportional and integral term in output.
4		$\frac{E_o}{E_i} = \frac{[1 + pC_1R_1][1 + pC_2R_2]}{p^2C_1R_1C_2R_2 + p[C_1R_1 + C_2R_2 + C_2R_1] + 1}$	Combines action of 2 and 3.
5		$\frac{E_o}{E_i} = \frac{A}{[1 + pC_1R_1][1 + pC_2R_2]}$	Buffer amplifier obviates loading of first stage, and transfer function is product of two elements similar to 1. Gives phase lag >90°.
6		$\frac{E_o}{E_i} = \frac{1}{p^2C_1R_1C_2R_2 + p[C_1R_1 + C_2R_2 + C_2R_1] + 1}$ If $C_1R_1 = C_2R_2$ $\frac{E_o}{E_i} = \frac{1}{p^2C_1^2R_1^2 + 3pC_1R_1 + 1}$	Differs from 5 in respect of coefficient of p in denominator.
7		$\frac{E_o}{E_i} = \frac{p^2T^2 + 2pT + b^2}{p^2T^2 + p(2 + b^2)T + b^2}$ where $T = CR$	Bridged T network. Used on a.c. servos. Gives approximate error rate term. Has finite signal output at carrier frequency.
8		$\frac{E_o}{E_i} = \frac{p^2b^2T^2 + 1}{p^2b^2T^2 + p2[1 + b^2]T + 1}$ where $T = CR$	Parallel T network. Similar action to 7 but can be designed to give zero output at carrier frequency.
9	D.C MOTOR (FIELD CONTROLLED) 	$\frac{\theta_o}{E_f} = \frac{K_t}{Jp^2[R_f + pL_f]}$ $\frac{\omega_o}{E_f} = \frac{K_t}{Jp[R_f + pL_f]}$ neglecting viscous friction $\frac{\theta_o}{E_f} = \frac{K_t}{p[pJ + D][R_f + pL_f]}$ including effect of viscous friction	Used in closed loop-control for position or velocity servo with field supplied from an amplifier. Split-field motor has similar transfer function but here K_t = torque/(difference of field currents). J = moment of inertia.
10	D C MOTOR (ARMATURE CONTROLLED) 	$\frac{\theta_o}{E_a} = \frac{K_t}{p[pJR_a + K_mK_t]}$ neglecting viscous friction $\frac{\theta_o}{E_a} = \frac{K_t}{p[pJR_a + DR_a + K_mK_t]}$ including effect of viscous friction	Motor armature can be controlled by an amplifier or from a generator, forming part of a closed loop, e.g. Ward Leonard speed control on closed loop.
11	D.C. GENERATOR 	$\frac{E_o}{E_f} = \frac{K_g/R_f}{1 + p\frac{L_f}{R_f}}$	Can be used on closed-loop operation as regulated power supply or as for 10.

DATA SHEET 1—*continued*

	ELEMENT	TRANSFER FUNCTION	REMARKS
12	AMPLIDYNE GENERATOR R_q and L_q are quadrature axis winding resistance and reactance respectively 	$\frac{E_0}{E_f} = \frac{K}{[R_f + pL_f][R_q + pL_q]}$	Used for high-power applications. Gives more rapid response than a conventional d.c. generator.
13		$\frac{E_0}{E_1} = -\frac{1}{pCR} \therefore E_0 = -\frac{1}{CR}\int E_1 dt$ If positions of C and R are interchanged $E_0 = -pCRE_1 = -CR\frac{dE_1}{dt}$	Items 13 to 16 are used extensively in analogue computing amplifiers, servo simulators, or in actual servo systems where the approximations associated with passive networks are not acceptable.
14		$\frac{E_0}{E_1} = -\frac{R_2}{R_1}\left[1 + pC_1R_1\right]$ $\therefore E_0 = -\frac{R_2}{R_1}E_1 - C_1\frac{R_2 dE_1}{dt}$	Output voltage contains proportional and derivative terms.
15		$\frac{E_0}{E_1} = -\left[\frac{R_2}{R_1} + \frac{1}{pC_2R_1}\right]$ $\therefore E_0 = -\frac{R_2}{R_1}E_1 - \frac{1}{C_2R_1}\int E_1 dt$	Gives proportional and integral terms in output.
16		$\frac{E_0}{E_1} = -\left[\frac{C_1}{C_2} + \frac{R_2}{R_1} + pC_1R_2 + \frac{1}{pC_2R_1}\right]$	Proportional, derivative and integral terms present in output.
17	K = Spring stiffness D = Dashpot damping force per unit velocity 	$\frac{x_0}{x_1} = \frac{1}{1 + p\frac{D}{K}}$	Transfer function analogous to 1. Has low-pass filter characteristics with respect to mechanical vibrations.
18		$\frac{x_0}{x_1} = \frac{p\frac{D}{K}}{1 + p\frac{D}{K}}$	Analogous to 1 with C and R interchanged. Acts as high-pass mechanical filter.
19		$\frac{x_0}{x_1} = \frac{1 + \frac{D_1}{K}p}{1 + \frac{D_1 + D_2}{K}p}$	Analogous to 3. Phase of x_0 with respect to x_1 is arc tan $\frac{D_1}{K}\omega$ − arc tan $\frac{D_1 + D_2}{K}\omega$ and gives net phase lag.
20		$\frac{x_0}{x_1} = \frac{K_1}{K_1 + K_2} \cdot \frac{1 + p\frac{D}{K_1}}{1 + p\frac{D}{K_1 + K_2}}$	Analogous to 2. Phase of x_0 is arc tan $\frac{D}{K_1}\omega$ − arc tan $\frac{D}{K_1 + K_2}\omega$ and gives net phase lead.
21	 M = Mass	$\frac{x_0}{x_1} = \frac{p\frac{D}{K}}{\frac{M}{K}p^2 + \frac{D}{K}p + 1}$	Analogue: 
22	 K = (Ram velocity) (Unit displacement of pilot valve stem)	Without feedback linkage $\frac{x_0}{x_1} = \frac{K}{p}$ or $x_0 = K\int x_1 dt$ With feedback linkage $\frac{x_0}{x_1} = \frac{K\left[1 - \frac{A}{E}\right]}{p + \frac{KA}{E}}$	Gives integrating action and hence relay is a non-corresponding type. Relay is a corresponding type and can act as position control. Mechanical time-constant variable by altering A. Transfer function can be modified by including elements such as 17 to 21.

NOTE: *An a.c. network of characteristics similar to a d.c. network can be derived by:*
(a) replacing each d.c. inductor by an inductor of half the value in series with a capacitor and tuned to resonate at a frequency of $\omega_0/2\pi$, the servo carrier frequency; and
(b) replacing each d.c. capacitor by a capacitor of half the value, with a parallel inductor tuned with the capacitor to resonate at a frequency of $\omega_0/2\pi$.

AN ELEMENTARY SURVEY OF DIGITAL CODES

by G. C. TOOTILL, M.A., M.SC., A.M.I.E.E.
Royal Aircraft Establishment, Farnborough

Nowadays nearly every engineer—and certainly any concerned with instrumentation—can calculate in terms of a straightforward binary scale if they need to. However the more recondite digital codes and their uses are not so well known. (One of these uses is surprising, and potentially lucrative, as readers of this article will discover.) Mr Tootill believes that the intriguing code of Fig. 2 (b) has not previously been published, but he does not claim that it is original.

Introduction: Groups of digits

This article is concerned with various different ways of listing, in order, groups of n digits. Where the different digit symbols are b in number, there are b^n such groups, and any correspondence established between some or all of these and consecutive integers will be called a 'code', the groups of digits being called 'code groups'. The Arabic number system with the value ten for b is an example of a code, and is so familiar that it is difficult to think of integers dissociated from their representations in this code. It is, however, merely one of the 'radix system' codes, whose special use is in arithmetic. It is proposed in this article briefly to describe various codes, classified by their main uses: Arithmetic; Analogue-to-Digital Conversion; and Data Transmission.

Codes for arithmetic

It seems unlikely that there will be devised anything better for arithmetic than a radix-system code. Its important feature is that the number corresponding to a group of digits ('represented' by the group of digits) is the sum of n contributions, each depending on the value of only one of the n digits in the representation. This lack of interdependence makes it possible to perform arithmetical operations one digit place at a time, a carry being all that is necessary to allow for the effect of digit places previously dealt with.

An algebraic representation is helpful. If the b different values that a digit can assume are identified with the integers 0 to $(b - 1)$, and if every integer in a certain range must have a unique representation, then it follows that

$$X = x_0 + x_1b + x_2b^2 + \ldots + x_{n-1}b^{n-1} + K \qquad \ldots (1)$$

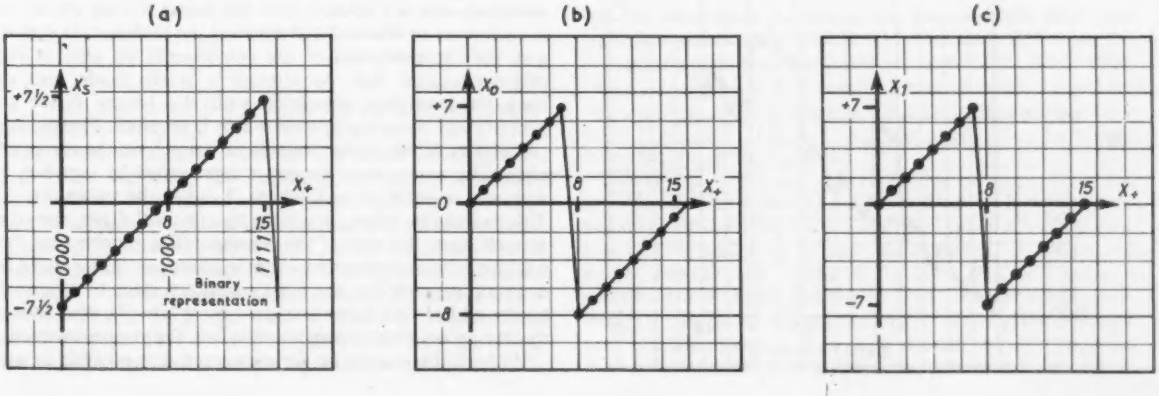
where X is an integer whose representation with radix (or base) b has digits $x_0, x_1, \ldots, x_{n-1}$, and $0 \leqslant x_i \leqslant b - 1$. The additive constant K takes the value zero in the 'positive integer' system and the range of numbers having representations is $0 \leqslant X_+ \leqslant b^n - 1$ (by consideration of the sum of a geometric progression). The implication of the suffix + is that X_+ is the integer that a given set of digits $(x_0, \ldots, x_{n-1})$ represents, in the positive integer system.

If $K = -\frac{1}{2}(b^n - 1)$, the 'symmetrical' system is obtained (X_s), the range of numbers represented extending symmetrically about zero (Fig. 1a). This has not been much used, because when b is even, as in the most important practical cases ($b = 2$ and $b = 10$), X_s is not, in fact, an integer, but lies halfway between consecutive integers. In particular, zero cannot be represented. In general, however, we have

$$\begin{aligned} X_s &= x_0 + x_1b + \ldots + x_{n-1}b^{n-1} - \tfrac{1}{2}(b^n - 1) \\ &= \xi_0 + \xi_1b + \ldots + \xi_{n-1}b^{n-1} \qquad \ldots (2) \end{aligned}$$

where $\xi_i = x_i - \frac{1}{2}(b - 1)$. This means that the digits in the representation can be thought of as ranging equally above and below zero, with K again zero. In the symmetrical ternary system ($b = 3$) a digit therefore takes the values -1, 0, or $+1$, making multiplication nearly as easy as the binary

Fig. 1 Radix system representation for four binary digits. (a) Symmetrical system. (b) Noughts complement system. (c) Ones complement system



system. Lack of a satisfactory three-state store has, however, prevented its use so far.

The most commonly used systems (where b is even) represent a negative number by the representation, in the positive integer system, of its complement. This is obtained by adding b^n to the number for the 'noughts-complement', and $(b^n - 1)$ for what is called the 'nines-' or 'ones-complement' according as whether b is ten or two. On this basis, any group of digits could represent two numbers, one positive, and one negative. This ambiguity is avoided by the convention (Fig. 1b and c) that when $X_+ < \frac{1}{2}b^n$, the number represented is X_+ itself; otherwise it is $(X_+ - b^n)$ or $(X_+ - b^n + 1)$. The widespread use of these two systems occurs because the processes of addition and subtraction are the same whether positive or negative numbers are being dealt with, and yet the most significant digit of a representation immediately gives the sign of the number. The noughts-complement system is used

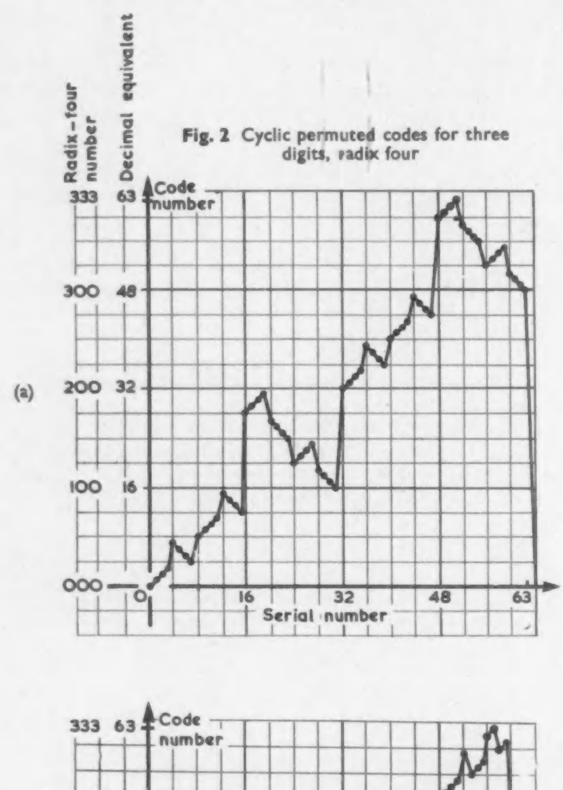


Fig. 2 Cyclic permuted codes for three digits, radix four

in serial binary computers, and the ones-complement system in some parallel binary computers, where 'end-around carry' is possible (*9*). An algebraic representation needs special treatment of the most significant digit (or 'top' digit), x_{n-1}, allowing it two contributions to X.

If

$$y = 0 \text{ when } x_{n-1} \leqslant \tfrac{1}{2}b - 1$$
$$y = 1 \text{ when } x_{n-1} \geqslant \tfrac{1}{2}b$$

then

$$X_0 = x_0 + x_1 b + \dots + x_{n-1}b^{n-1} - yb^n \quad \dots \text{(3a)}$$

and

$$X_{b-1} = x_0 + x_1 b + \dots + x_{n-1}b^{n-1} - y(b^n - 1) \quad \dots \text{(3b)}$$

In radix two (where $y = x_{n-1}$), the effect of this is to make the weight of x_{n-1} negative, i.e. its contribution is 0 or -2^{n-1} for noughts-complements, and 0 or $(-2^{n-1} + 1)$ for ones-complements. A modification can be made to binary noughts-complements representation, where x_{n-1} is negated (i.e. nought is replaced by one and vice versa). Denoting by X_{om} the number corresponding to the group of digits in this interpretation, we have:

$$X_{om} = x_0 + x_1.2 + \dots + x_{n-2}.2^{n-2} - (1 - x_{n-1})2^{n-1} \quad \dots \text{(3c)}$$

the top digit being 1 for positive numbers and 0 for negative. This representation is used in binary digital differential analysers (*8*), and is the special case of equation 1 where $b = 2$ and $K = -2^{n-1}$.

A less useful representation is the modulus and sign system, where the absolute value of the number is represented in the positive integer system, and an extra binary digit records the sign. The disadvantage of this system is that what is nominally, say, addition becomes one of two

0	0101
1	0001
2	0011
3	0010
4	0110
5	1110
6	1010
7	1011
8	1001
9	1101

Fig. 3 A code suitable for decimal digitizers

types of subtraction if the signs of the two numbers differ. It is, however, a better system for use in multiplication, and conversion between this and the noughts-complement system is performed in some computing machines (*13*).

When it is desired to make a decimal computer from binary elements (*10*), four binary digits are used to represent each decimal digit, which forms what is called a 'binary-coded decimal' system. In these specialized codes, six of the representations are not needed, and this leaves a wide choice. It is customary to demand that negating the representation shall give the representation of the complement on nine of the original decimal digit. An attempt is usually made, also, to have fixed weights associated with the binary digits, to simplify any decoding process which is required. Finally, the complexity of the adder depends very much on the choice of code. The *excess-three* system is represented by equation 1 with $n = 4$ and $K = -3$, where X takes the values 0 to 9. This means that when, in adding two decimal digits, the sum exceeds nine, the sum of the corresponding numbers on the positive integer convention exceeds fifteen, so that a carry is correctly generated at the most significant stage of a normal binary adder. This topic is treated by White (*7*), who shows that the excess-three system is not, in fact, the most economical.

With all the systems so far mentioned it is possible to use

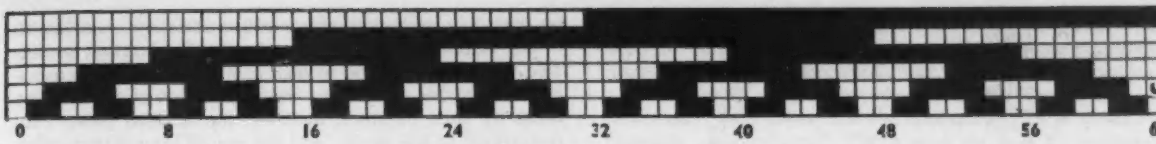


Fig. 4 Six-digit reflected binary c.p. codes

a *floating-point* system. An auxiliary number specifies the power of b by which the main number is to be multiplied before use (*13*). This facility is beginning to be thought essential for general-purpose computers.

A system which eliminates the need for inter-digit carries in addition, subtraction and multiplication has been proposed by Wijngaarden (*6*). The value of b is not constant, but is successive prime numbers (2, 3, 5, 7, 11, . . .) in successive digit places. If, however, the practical difficulties of a variable radix could be surmounted, there would still remain the theoretical difficulty of finding a way to do division.

Codes for analogue-to-digital conversion

A fundamental difficulty exists in automatically generating a parallel digital representation of, say, the angular position of a shaft. If the shaft carries three scales, each reading one decimal digit of the representation of the angle in degrees, then all three readings must change at the transition, e.g. from 199° to 200°. The necessity for dimensional tolerances means that there will be transitional shaft positions where all three changes have not occurred, so that intermediate readings of e.g. 299° and 209° are given. If the reading must be capable of being taken when the shaft is stationary, some means of avoiding these gross errors (for which the name 'ambiguities' is often reserved) must be devised. One class of methods (*12, 14*) which is becoming more popular, provides for minor displacement of the reading station for the more significant digits according to the values of the less significant digits, the number being read in a radix system code. Another approach is the use of a code in which only one digit changes at the transition from one group of digits to the next. Such a code is called a *cyclic permuted* (*c.p.*) code. The initials are sometimes taken to mean 'continuous progressive'. Two systematic ways of constructing such codes are known; for two-decimal digits they are:

(*a*) 00, 01, 02, . . ., 09, 19, 18, 17, . . ., 10, 20, 21,22, . . .,

(*b*) 00, 01, 02, . . ., 09, 19, 10, 11, 12, . . . 18, 28, 29
20, 21, 22, . . ., 27, 37, 38, 39, 30, 31, 32, . . .

The same codes are illustrated for three radix-four digits in Fig. 2. This relates the serial numbers S of the code groups in the c.p. code (as abscissa) to the number C they would represent if interpreted in the positive integer system.

System (*a*) is used, with radix ten, in the analogue-to-digital convertors ('digitizers') designed in the Royal Aircraft Establishment (*18, 16*).

It has the advantage that S may readily be found from $c_0 \ldots, c_{n-1}$, since s_i is given by:

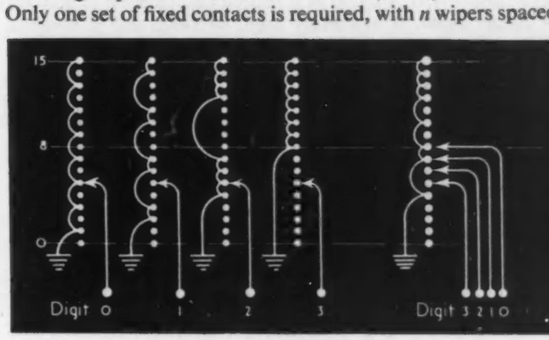
$$\begin{aligned} s_i &= c_i && \text{when } s_{i+1} \text{ is even} \\ s_i &= b - 1 - c_i && \text{,, ,, ,, odd} \end{aligned} \qquad \ldots (4)$$

the lower-case letters being digits in the positive integer representations of S and C.

The conversion starts from the top digit, where $s_{n-1} = c_{n-1}$. These digitizers, like others commercially available, consist effectively of sets of rotary ganged switches. The basic signal is a binary one, being either an earth or an open-circuit on each of numerous output wires, so that a binary-coded decimal system is indicated. Ease of forming the complement on nine of a decimal digit is necessitated by equations 4, and the ten 4-digit binary groups must have the c.p. property. The groups 0000 and 1111 are perhaps more likely than the others to arise as the result of a fault. If they are not used in the code proper, they can have the meaning 'system faulty' attached to them. A suitable code is shown in Fig. 3 (*16, 18*).

System (*b*) of Fig. 2 is less well known than system (*a*), but both systems reduce to the *reflected binary c.p. code* (*1*) in radix two; this is often called the *Gray code* in the USA. The structure is shown very clearly in Fig. 4, where the black squares represent the binary digit 1, and the white squares, 0. What is known as the *parity digit* ('parity' meaning oddness or evenness) may be added to the code groups at the least significant (bottom) end, taking the value 0 when S is even and 1 when S is odd. Because of the c.p. property, this makes the parity of all code groups even; stated alternatively, the value of the parity digit can be deduced from the code group. Thus augmented, the code groups can be shifted in the direction of increasing significance to double, quadruple, etc, the corresponding serial number. This code and modifications of it have also been used for shaft rotation digitizers (*4*).

If 'ambiguities' can be avoided by means other than a c.p. code (e.g. by a detent or geneva-cam mechanism), the positive integer system can be used. The obvious way to achieve this for, say n binary digits, is to use n ganged single-pole 2^n-way switches with the fixed contacts wired as indicated in Fig. 5a. If the requirement however is merely to indicate unequivocally the angular position, with no need for arithmetic such as would be required, for instance, in computing the error signal in a servomechanism, then an economy can be achieved by the use of what is called a *chain code*. This is a cyclic arrangement of the 2^n n-digit groups such that the last $(n - 1)$ digits of one group are the same as the first $(n - 1)$ of the next. Only one set of fixed contacts is required, with n wipers spaced



(a) (b)

Fig. 5 Wiring of digitizers for four binary digits. (a) Positive integer system. (b) Chain code

one quantum apart, as in Fig. 5b. The wiring on the fixed contacts represents 0000100110101111 in this 4-digit example; in successive positions the numbers 0000, 0001, 0010, 0100, 1001, . . . occur at the output, going through the sixteen combinations without repetition. A rule for generating chain codes is available (*11*), but up to the present they have been of mainly theoretical interest.

Binary c.p. codes are also useful for counting (*15*). The counter contains a parallel n-digit register R which is to hold a digit-group denoting the cumulative number of input pulses. If a radix-system code is used, the operation of adding one to this number may change all the digits, and so requires a second parallel digital register to hold the total temporarily, before it can be transferred back to R. If a c.p. code is used, only one digit place in R must be altered, so that temporary storage for one digit only is necessary. Even where the tempor-

(a)	
1	10000
	11000
2	01000
	01100
3	00100
	00110
4	00010
	00011
5	00001
	10001

(b)	
0	0000
	0001
1	0011
	0010
2	0110
	0111
3	1111
	1011
4	1001
	1101
5	0101
	0100
6	1100
	1110
7	1010
	1000

Fig. 6 Binary c.p. codes for use in relay counters
(a) For the 'ring' type
(b) For equalizing wear in a less-redundant circuit

ary storage is cheap (e.g. condensers in electronic counters), a c.p. code may be used to prevent 'ambiguities' in reading R while the count is changing. A relay ring counter works in a c.p. code (Fig. 6a), since one relay operates at the start of an input impulse, and one relay releases at the end. Only $2n$ out of 2^n possible digit groups are used; a circuit with no redundancy can use the reflected binary c.p. code or the code of Fig. 6b, where there are the same number of changes in each column. This latter has the effect of spreading the wear evenly between the relays.

Codes for data transmission

When code groups are transmitted from point to point inside a piece of digital apparatus there is no difficulty in recognizing the end of one group and the beginning of the next, since master timing signals are available on a separate channel. When a telephone line or a radio link is employed for transmission, a signal of a special nature, such as a larger or longer pulse, is frequently used, although this is wasteful of signalling capacity of the channel. Provided that synchronization of digit frequencies at the transmitting and receiving ends can be achieved, with perfect apparatus, group synchronization could be achieved by counting digit periods from the start of the transmission. In fact, for a type of 'optimum coding' (*2*) which uses shorter groups for commoner symbols, the end-of-group information is inherent in the code. Most of the modern developments, however, intended to combat the effects of noise in the transmission link, require extraneous means for group synchronization. In the system described by Barker (*5*), a prearranged synchronizing group can be transmitted regularly, interleaved with the more numerous information-bearing groups, and group synchronization can be maintained in spite of noise in the transmission link.

The requirement for correct reception of the information in the presence of such noise is met by the provision of redundancy, sufficient in the first conception to enable a single error to be detected at the receiving end by an internal inconsistency in the code group. Such an 'error-detecting' code would be used to call for repetition of erroneous groups. By the provision of further redundancy, not only the existence, but also the nature, of an error can be indicated by an 'error-correcting' code. Nearly all the published work relates to binary code groups, and with these a single error in a group of n digits will alter the parity of the group. Adding a parity digit to each group, whose value is assigned to make the parity of the composite $(n + 1)$ digit group always the same, will therefore allow a single error in a group to be detected. Clearly the value of n must be made small enough, having regard to the signal/noise ratio in the transmission link, to make the probability of two errors in the same group tolerably small, since these will escape notice.

The basis of binary error-correcting codes can be explained by regarding each code group as the cartesian co-ordinates of one vertex of an n-dimensional cube. Only certain nominated vertices correspond to digit groups which can be transmitted (the code groups); owing to alteration of one or more digits by noise impulses, however, the received group may correspond to any vertex, and the nearest code-group vertex to this is taken as the correct one. In fact, the distance apart along edges of the n-dimensional cube [the *Hamming distance* (*3*)] is the number of digit places in which the two code groups differ. Since each error moves the received point unit distance, in order to correct up to one error per digit group, the code groups must nowhere be closer together than three units. (If two code groups were two units apart there would be a vertex equidistant from them, and if this one were indicated by the receiver, the error would not be correctable.) On the other hand, for maximum economy in channel capacity, no vertex must be further from some code group vertex than one digit (the 'close-packing' requirement). That is, no digit group must differ from some code group in more than one digit place. It is not possible to satisfy both these requirements unless $n = 2^m - 1$; a code for $n = 7$ is given in Fig. 7. For any one of the 128 seven-digit binary numbers there is one of these sixteen code groups which differs in no more than one digit position.

If all the code groups are at least four units apart, single errors can be corrected and double errors detected. In fact, to correct up to e errors, the code groups must be $(2e + 1)$ units apart, and to correct up to e errors and detect $(e + 1)$ errors, $(2e + 2)$ units apart. If it is merely required to detect up to e errors, the code groups need only be $(e + 1)$ units apart.

It is clearly undesirable to construct this type of code by

	1243567
0	0000000
1	1110001
2	0110010
3	1000011
4	1010100
5	0100101
6	1100110
7	0010111
8	1101000
9	0011001
10	1011010
11	0101011
12	0111100
13	1001101
14	0001110
15	1111111

Fig. 7 Binary code for correcting up to one error (Hamming)

0	0000
1	1201
2	2102
3	1110
4	2011
5	0212
6	2220
7	0121
8	1022

Fig. 8 Radix-three code for correcting up to one error.

unaided trial and error, but the state of the art is unsatisfactory. In what are called 'systematic' codes, each code group consists of information digits and juxtaposed check digits. Any value may be given to the information digits, and the corresponding values for the check digits are then determined. In Fig. 7 the first three digit positions (numbered 1, 2, 4) contain the check digits, the remaining four exhibiting all the sixteen combinations of four binary digits. Digit 1 is chosen for even parity of digits 1, 3, 5 and 7, digit 2 the same for digits 2, 3, 6 and 7, digit 4 the same for digits 4, 5, 6 and 7. This choice of checking positions means that if the corresponding three parity checks are made on the received code group in the order indicated, 0 being recorded for even parity (correctness) and 1 for odd, the three-digit binary number produced will be the positive-integer representation of the number of the erroneous digit position, position 0 meaning no error.

Lloyd (*17*) has investigated close-packed binary codes for

correcting up to e errors. He concludes that for $n \leqslant 150$, the only codes, systematic or otherwise, which exist are:

(*a*) $e = 1$, $n = 2^m - 1$, as above

(*b*) $n = 2e + 1$, the 'majority rule' codes with only two code groups

(*c*) $e = 3$, $n = 23$

Less effort has been devoted to other radices. The geometrical model is not serviceable, but the term 'distance apart' can still be used for the number of digit places in which two code groups differ. In radix three, with $e = 1$ close-packed codes may exist for $n = \frac{1}{2}(3^m - 1)$, e.g. $n = 4$ in Fig. 8; and with $e = 2$ there may be a code consisting of 729 code-groups for $n = 11$.

A correspondence exists between error-correcting codes and 'permutations with a guarantee' in a football 'results pool'. Suppose it is required to forecast the results of n football matches with no more than e errors, the gambler's minimum stake being proportional to his number of attempts. Since the result of a match must be 'win', 'lose' or 'draw', a radix-three notation is indicated, unless one outcome for each match can be confidently excluded, to reduce the radix to two. One forecast covers a number of possible results distant up to e from it, and so to keep the total stake to a miminum, forecasts must be distant $(2e + 1)$ from each other. The close-packing requirement ensures that all results are covered to produce the 'guarantee'. Fig. 8 is well known as a permutation to guarantee three out of four with three-way forecasts.

Summary

The widespread application of digital techniques in recent years has given rise to a great variety of codes, which are described piecemeal in the literature. An attempt has been made here to survey and correlate the more important ideas, for the benefit of the non-specialist. Most important are radix-system codes on which arithmetic is based, and several variants are described with their spheres of usefulness. The need to convert from analogue to digital representations introduced the cyclic permuted codes, which are explained for a general radix before the reflected binary special case is described. Chain codes, and the application of c.p. codes to counters, are mentioned. The section on data transmission gives an elementary explanation of error detecting and correcting codes. The highly mathematical aspect of this topic, namely the statistics of signalling in the presence of noise, is not covered. Sufficient references to the literature are given throughout to allow a particular topic to be followed up, and some of the specialized terminology is explained.

REFERENCES

1. Standard Telephones and Cables Ltd: *Provisional Patent* 29595, 1948
2. Shannon, C. E.: 'A Mathematical Theory of Communication' *Bell Syst. tech. J.*, 1948, **27**, p 379
3. Hamming, R. W.: 'Error Detecting and Error Correcting Codes' *Bell Syst. tech. J.*, 1950, **29**, p 147
4. Johnson, E. A.: 'Telerotation and Telegoniometry using parallel binary coding'. Unpublished Ministry of Supply Report
5. Barker, R. H.: 'Group Synchronising of Binary Digital Systems' *Symposium on Applications of Communication Theory* (Butterworth, 1952)
6. Wijngaarden, A. van: 'Automatic Digital Co.nputation' *Proceedings of a Symposium held at the National Physical Laboratory* (HMSO, 1953), p 124
7. White, G. S.: 'Coded Decimal Number Systems for Digital Computers' *Proc. Inst. Radio Engrs*, October 1953, **41**, No 10, p 1450
8. Mendelson, M. J.: 'The Decimal D.D.A.' *Aeron. Engng Rev.*, February 1954 **13**, p 42
9. Wilkes, M. W.: 'Automatic Digital Computers' (Methuen, 1956), p 39
10. *Ibid*, pp 239–50
11. Goodstein, R. L.: 'Mathematical Notes 2590' *Mathematical Gazette*, February 1956, **XL**, No 331, p 46
12. Barker, R. H.: 'A Transducer for Digital Data-Transmission Systems' *Proc. Inst. Elect. Engrs*, 1956, **103**, Part B, p 42
13. Kilburn, T., Edwards, D. B. G., and Thomas, G. E.: 'The Manchester University Mk. II Digital-Computing Machine' *Proc. Inst. Elect. Engrs*, 1956, **103**, Part B, Supplement 2, p 247
14. Elliott, W. S., Robbins, R. C., and Evans, D. S.: 'Remote Position Control and Indication by Digital Means' *Proc. Inst. Elect. Engrs*, 1956, **103**, Part B, Supplement 3, p 437
15. Tootill, G. C.: 'The Use of Cyclic Permuted Codes in Relay Counting Circuits' *Ibid*, p 432
16. Petherick, E. J.: 'Some Recently Developed Digital Devices for Encoding the Rotations of Shafts and the Displacement of Slides'. Unpublished Ministry of Supply Report
17. Lloyd, S. P.: 'Binary Block Coding' *Bell Syst. tech. J.*, March 1957, **36**, p 517
18. Tiffany, A.: 'A Simple Shaft Digitizer and Store' *Electronic Engng*, December 1957, p 568

LOOKING AHEAD

A diary for the next three months

JULY 14–18 — *Computers in Operation*: A series of lectures to be given at the Northampton College of Advanced Technology, St John St, EC1. Details of the lectures, on the daily work carried out on standard computers, are obtainable from the Mathematics Dept.

AUG 18–23 — *International Conference on Semi-Conductors*, in Rochester, New York. Details from Dr M. H. Hebb, Conference Secretary, General Electric Research Laboratory, PO Box 1088, Schenectady, New York.

AUG 23–SEPT 2 — *International Fair of Technics and Technical Achievements*, in Belgrade. Details from Auger & Turner Group Ltd., Autur House, 40 Gerrard St, W1.

AUG 27–SEPT 3 — *120th Annual Meeting of the British Association for the Advancement of Science*, in Glasgow. This year's President is Sir Alexander Fleck, Chairman of ICI. A paper will be read on automatic control and instrumentation, with special reference to nuclear plants. Details from the Secretary, British Association, Burlington House, Piccadilly, W1.

SEPT 1–7 — *The Farnborough Air Show* is expected to see the first public appearance of the de Havilland Comet IV and the pilotless English Electric Canberra target aircraft. Details from the Society of British Aircraft Constructors, 29 King St, St James's, SW1.

SEPT 1–13 — *Peaceful Uses of Atomic Energy*, at Geneva. Details of the second international conference are obtainable from The Secretary, The Executive Committee 1958 Geneva Conference, Atomic Energy Research Establishment, Harwell, Didcot, Berks.

SEPT 3–10 — *2nd International Conference on Cybernetics*, at Namur. Details from the International Association for Cybernetics, 13 rue Basse-Marcell, Namur, Belgium.

SEPT 16–20 — *International Symposium on Nuclear Electronics*, in Paris. Details from Colloque International 'Electronique Nucléaire', 10 avenue Pierre-Larousse, Malakoff (Seine), France.

COURSES

SEPT 8–12 — Summer School on *The Principles and Practice of Non-destructive Testing*, in Manchester. Details from The Registrar, The Manchester College of Science and Technology, Manchester 1.

SEPT 15–19 — *Applications of Computers*. A week's residential course at Nottingham University. Details from The Organizing Secretary, Applications of Computers Course, Dept of Mechanical Engineering, The University, Nottingham.

SEPT 15–19 — Summer School in *Instrumentation and Telemetering*, at the Northampton College of Advanced Technology, St John St, EC1. Details from the Dept of Instrument Engineering.

SEPT 22–26 — Summer School in *Automatic Process Control* at the Northampton College of Advanced Technology, St John St, EC1. Details from the Dept of Instrument Engineering.

SEPT 29–JUNE 26 '59 — Postgraduate Course in *Instrumentation and Process Control*, at the Northampton College of Advanced Technology, St John St, EC1. Details from the Secretary.

CONTROL IN ACTION

Comet flying controls

Hydraulics power ailerons, rudder and elevators

THE DE HAVILLAND Comet IV, now in full production, will be brought into service with BOAC in a few months' time. In this article a member of CONTROL's staff outlines the operation of the power-operated flying controls, which are improved versions of those used on earlier marks of the Comet.

These controls are indeed the result of an intensive programme to develop a reliable, rugged system, a programme which has included the testing of the complete system in a full-scale ground rig.

In common with most fixed-wing aircraft the Comet IV has three primary flying control-surfaces: the ailerons, the elevators and the rudder. These surfaces and the secondary surfaces, the flaps and the airbrakes, are operated by hydraulic units using Lockheed 22 hydraulic fluid at a pressure of 2500 lb/in². Hydraulic power is also used for the undercarriage, the wheel brakes and the nose-wheel steering. The hydraulic system is separated into four independent colour-coded circuits: Blue, Green, Yellow and Red. The Blue circuit operates the aileron, elevator, and rudder hydraulic servo units (Lockheed Servodynes) only. The Green circuit operates the undercarriage, flaps, airbrakes and wheel brakes, and is also an emergency source of supply for the aileron, elevator and rudder secondary Servodynes. The Yellow system is a second emergency system for the aileron, elevator, and rudder Servodynes and is a completely independent system. The Red circuit is the emergency system operating the undercarriage flaps and wheel brakes. A hand pump enables the undercarriage to be lowered and also allows the replenishment of any reservoir during flight from a reserve hydraulic tank. Each of the four main engines drives a Lockheed hydraulic pump, two supplying the Blue circuit and two the Green. The Red and Yellow circuits have separate pumps driven by BTH electric motors.

Ailerons

The ailerons are the flying control surfaces on the main wing and they control the lateral direction of the aircraft. A rotation of the pilot's half-wheel will cause one aileron to move up as the other moves down, thus rolling the aircraft to that side which has the upward-moving aileron. The elevators are the control surfaces on the tailplane and they are moved together to control the longitudinal flight path. An upward movement will bring the nose of the aircraft up and a contrary movement will bring the nose down. The rudder is the vertical control surface and moves the aircraft to port or starboard. Normally the rudder is used in conjunction with the ailerons to produce a banking action in order to turn the aircraft. In automatic flight the Smith's SEP2 autopilot flies the aircraft using the ailerons and elevators only. The Comet ailerons, rudder and elevators are operated by Servodynes, the control valves of which are connected by duplicated wire cables and connecting rods to the dual pilot-operated controls at the cockpit. The Servodynes are mounted with the piston rod fixed so that the

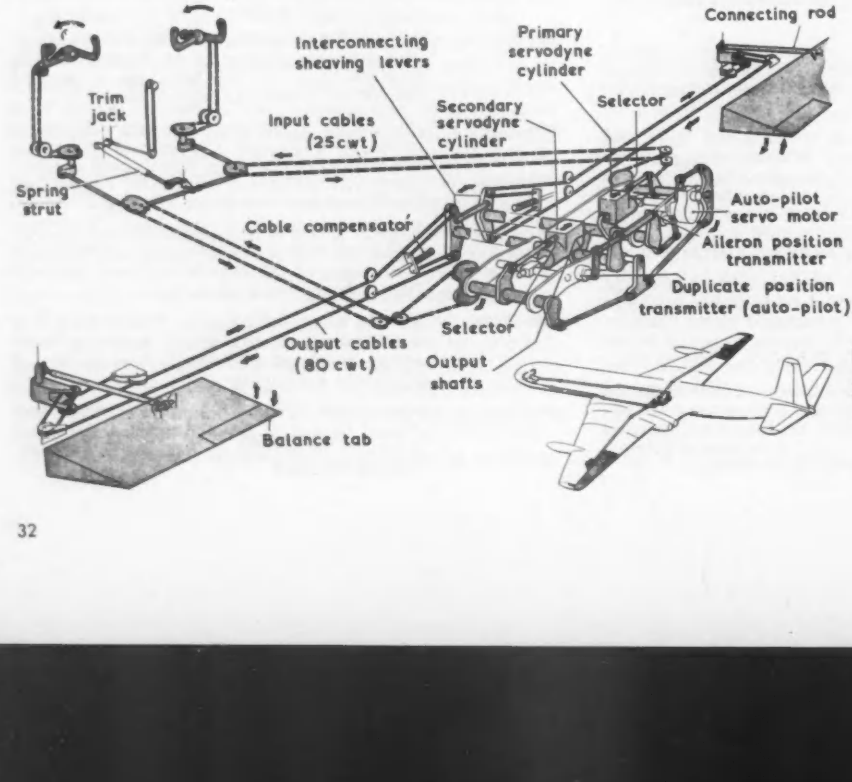


Fig. 1 Aileron control system
Arrows indicate direction of travel when port aileron is applied. All main moving components are shaded

main cylinder, with its control valve, is free to move. In response to a displacement of the valve the Servodyne will move in such a direction as will bring the control valve to the neutral position. The valve requires approximately half-a-pound effort to operate it. This initiates movement of the Servodyne, which is capable of exerting a large effort. The Servodynes are duplicated so that if a fault occurs in one the other is immediately available.

The Comet IV aileron control system is shown in Fig. 1. The pilot's controls are biased to the central position by a double-acting spring strut. An anticlockwise rotation of the pilot's half-wheel is transmitted by a mechanical linkage to a pair of pulleys, one each side of the cockpit, under the floor. From each of these pulleys a pair of cables passes down the respective sides of the fuselage to another pulley and mechanical linkage, which, when rotated moves the Servodyne operating valve. This 'input' circuit is mechanically interlinked at both the cockpit and the Servodynes. The linear motion of the Servodynes is translated into a rotary motion by simple levers and shafts. On the 'output' side of these shafts is a pair of sheaving levers attached to the ailerons by lengths of output cables in such a way that as the starboard aileron moves up, the port aileron moves down by the same amount. The output circuit is mechanically linked at the Servodynes. During automatic flight the autopilot controls the ailerons by a servomotor which moves the mechanical input to the Servodyne operating valve. Under normal operation, only the right-hand Servodyne is under hydraulic (Blue) power. In the event of failure a control lever in the cockpit allows the pilot to change to the left-hand unit, which has a separate (Green) power supply. If a second failure occurs the pilot can switch on the emergency (Yellow) supply, which also powers only the left-hand unit, but through a separate pipe circuit.

Elevators

The elevator control circuit is shown in Fig. 2. The principle of the circuit is the same as that for the ailerons, with the difference that the primary and secondary Servodynes are side by side. A movement of the stick towards the pilot results in the primary Servodyne moving aft, and therefore since the primary and secondary Servodynes are mechanically linked on both the input and output sides, the secondary Servodyne moves aft as well. The Servodynes are connected to the elevators by push-pull connecting rods. The secondary and emergency hydraulic circuits function in a similar manner to the aileron system. As the speed of the aircraft increases, its response to the elevator becomes more sensitive, and to compensate for this a gear change unit is incorporated in the connecting rods. This unit changes the mechanical advantage of the rods so that at the higher speeds the full stick displacement produces a much smaller movement of the elevator than it would at lower speeds. Manual selection of the gear change unit is by two-position switches on the pilot's central control pedestal. The setting at which full elevator movement is obtained is labelled COARSE and the setting which gives approximately 54 pc elevator movement is labelled FINE. The FINE position is the normal one for flight, apart from take-off and landing. If the aircraft exceeds its limiting Mach number, automatic trimming will bring the nose of the aircraft up to effect a reduction in speed. At the other end of the speed range, a stick shaker indicates to the pilot that the aircraft is near its stalling speed by shaking the column. Another feature of the elevator circuits is that as the pilot increases the deflexion of the stick from the neutral position he meets with increasing resistance, this resistance also varies with the speed of the aircraft. This is known as 'q-feel' and is used to limit the elevator angle that the pilot can apply at high speeds. It is introduced by a pneumatic cylinder through a linkage to the input connecting rods. The cylinder is of a large diameter and has a tandem piston, with dynamic pressure applied to one side and static pressure to the other.

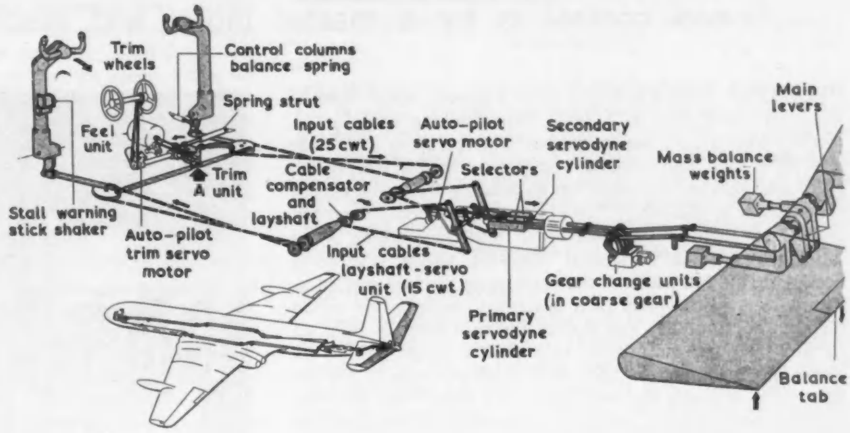


Fig. 2 Elevator control system
Arrows indicate direction of travel when elevator 'Up' is applied. All main moving components are shown shaded

Rudder and flaps

The rudder control system is operated by foot pedals and operates a Servodyne through wire cables. The dual controls are mechanically coupled and there are two linked Servodynes as in the elevator circuit, but there is only one set of cables to the input valves. In the event of failure of the input circuit the light cable rudder-trim circuit, which is entirely separate from the input circuit, would allow the pilot to move the rudder through ten degrees in each direction; this movement is perfectly adequate for normal flight. Any tendency of the aircraft to deviate in a horizontal plane from the line of flight (i.e. yaw), is controlled by a damping unit fitted on the input cable compensating pulley. The yaw damper is actuated by a gyroscope and is in continuous operation. No 'q-feel' is fitted to the rudder circuit but a positive-stop limiting device restricts the movement at high speed. Restrictions on the elevator and rudder movements are necessary, because a large movement of either at high speed would result in a violent manoeuvre which might severely stress, if not damage, both the airframe and the passengers.

The main purpose of the flaps is to reduce the stalling speed of the aircraft. Each Comet IV mainplane is provided with four flaps. The inner pair are of the split type, i.e. they move downwards from a fixed structure, and are situated under the

engine and part of the fuselage. The outer pair are of the plain hinged trailing-edge type and are between the engines and the aileron. One servo unit powers both pairs of inner flaps, through cables to the quadrants on the flaps. The plain flaps are actuated by a servo unit in each main plane. The relative angular position between the split and plain flaps is determined by the cams of a proportioner unit, through which selection of the three servo units is made from the pilot's flap lever. The pilot can preselect one of a fixed number of openings and the flaps will take up the position as quickly as fluid can be supplied to the Servodynes. If a failure occurs in the plain flaps the split flaps will still operate, and vice versa, a mechanical linkage prevents one plain flap going down without the other. The air brakes are on both top surfaces of the mainplane and are actuated by two jacks in each wing.

In automatic flight the angular positions of the ailerons and elevators are transmitted to the autopilot and the necessary corrections applied to the Servodyne operating valves through electric motors of the hysteresis type attached to the input operating levers. It is possible to feed radio and instrument information to the autopilot to simplify approach-pattern flying and navigation.

In the following months as the Comet IV is brought into service with BOAC the handling qualities and reliability built into the aircraft as a result of years of ground test work will be critically examined by many pilots and operators.

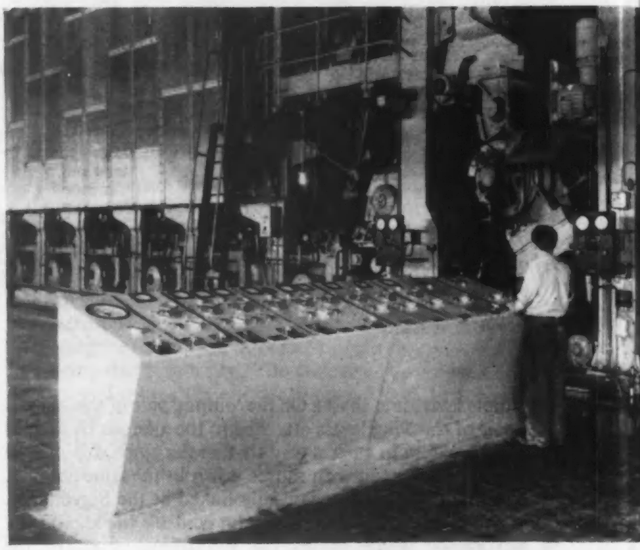
A new paper machine

Speed control is by a master motor and mechanical differentials

PROBABLY THE BIGGEST (and costliest) single item of industrial equipment is a large paper-making machine. A modern Fourdrinier paper machine may be up to 25 ft wide and 300 ft long, and contains numerous revolving rolls which guide and process the paper on its journey from one end of the machine to the other. Paper is usually produced from wet wood pulp (often mixed with other materials) which is fed uniformly onto a horizontal fine-wire screen (the *wire*) occupying the full width of the machine at the 'wet end' of it. The wire is in the form of a horizontal endless belt which revolves continuously and carries the thin layer of pulp on its way from the pulp feeder to a suction *couch roll* further along the machine. At the same time the wire is shaken laterally to entangle the pulp fibres, and water from the pulp drains away through it. But the pulp arriving at the couch roll is naturally still very wet and must be compressed and dried before it becomes paper. From the couch roll it is transferred to an endless wool felt blanket which moves continuously round a system of rolls, and it then passes between revolving press rolls which remove some water mechanically and form it into a damp matted sheet of fibres; next, carried on other felts, the embryo sheet passes over numerous revolving steam-heated cylinders. The sheet of paper is progressively dried until it reaches the calender rolls and the winding reel at the 'dry end' of the machine. To produce paper of a uniform quality, it is very important that the speeds of the rolls along the length of the machine are maintained constant, and a feedback control system is normally used on a number of individually driven rolls. Other rolls may be individually driven, but only controlled in speed by the load imposed by the moving felts. Many smaller rolls are trailers and are driven by the felts. Since the sheet of paper shrinks slightly as it dries on its journey through the machine, the controlled circumferential speeds of the driven rolls must not all be quite the same; the operating of this speed variation of a few per cent is known as *draw control*.

The Dartford machine

One of the newest Fourdrinier paper-making machines in Britain is that which has recently been installed in a new mill at Dartford, Kent. This mill is owned by Wiggins Teape Ltd, and has been built within a few hundred yards of the firm's older mill on the banks of the Dartford creek. The trials on this machine, of wire width 204 in., were completed last month, and it is now in full operation. The machine will normally run continuously seven days a week, and will be used to make packaging and writing papers. Harland Drives



The wet end control desk for the drives, containing the operator's controls for the couch and press sections, together with the overall speed control switch indicator

Ltd, a subsidiary of the Harland Engineering Co Ltd, were responsible for the design and installation of all the drives for the machine, which to a large extent follow the company's standard practice, well tried in many paper mills at home and oversea. Fourteen of the rolls in it are individually driven by d.c. compound-wound motors revolving at speeds between 986 and 1330 r.p.m., with gearing to give a speed reduction of up to 9·75 : 1. Eight of these motors (driving the couch roll, first press bottom roll, second press, lead drier, main drier, after drier, calender and reel) are accurately controlled in speed by comparison with the speed of a master motor. The drive motors are situated in the paper-machine room, with the master motor in a separate control room. The individual motors have ratings of between 10 and 225 h.p., depending on the rolls they drive, but the rating of the master motor is only 2·5 h.p., since it is required as a speed reference only, and the load on it is small. This reference speed can be varied by altering its armature voltage, which is fed direct

from the main motor-generator set supplying the equipment. The motor generator's output voltage can in fact be varied so that the speed of the paper in the machine can be set at any value from 231 to 1500 ft/min, a voltage of 550 V corresponding to 1500 ft/min. The field voltage of the master motor is nominally 250 V.

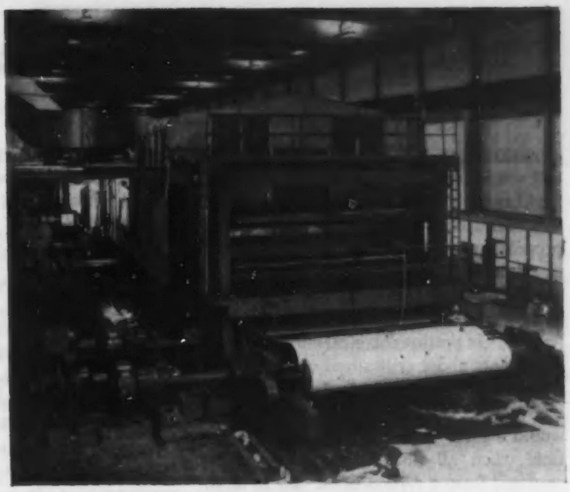
The automatic speed regulators

Once the desired paper machine speed has been established on the master motor, the individual motors, on pressing the 'run' buttons, will run up automatically to the desired speed, and when it is reached, automatic speed regulators are switched into circuit and control the eight motors as follows. Essentially the angular position of the rotor of each drive motor is compared with the angular position of the rotor of the master motor in a simple differential unit. As will be seen later, the input to the differential from the drive motor is taken by a variable electromechanical coupling which allows slight speed adjustment. The differential consists of a nut threaded onto a screw-shaft, the nut being prevented from moving axially (but not the shaft). When the two motors are rotating at the same speed, the screw-shaft makes no linear (i.e. axial) movement. But, if the drive motor changes speed owing to, say, an alteration in load, the screw-shaft moves axially; through a mechanical linkage acting against a spring, it alters the pressure on a carbon-pile regulator, thus changing the regulator's resistance. This regulator is connected in the field circuit of the drive motor and acts as a speed controller. The motor's speed is restored to the desired value, when the screw-shaft ceases to move along its axis.

The nut in the differential unit is driven through skew gears by the master motor. The variable electromechanical coupling to the screw-shaft is produced as follows. On an extension of each drive motor's shaft are three slip rings connected to the armature of the motor, giving a three-phase output whose frequency is directly proportional to the speed of the drive motor. This supplies a three-phase synchronous motor which drives through cone pulleys and spur gears the screw-shaft in the differential unit. Belt-shifting gear allows the cone pulley drive to be varied so that the desired speed of the motor can be shifted (for draw control) over a range of $\pm 7\frac{1}{2}$ pc. The belt-shifters, which are designed to have a dead-beat operation, are operated by solenoids, controlled from desks in the paper-machine room. A feature of the control equipment at Dartford is that the section draw

Part of the control room showing the differential regulator assembly, and the crawl generator set. The master motor can be seen in the middle of the eight differential regulators

controls can be arranged for individual section operation or progressive operation on either side of the master draw



Some of the Harland drive motors seen from the reel end of the machine

reference section. Selection of either system is effected by the operator through switches located on the front of the machine control stations. There is, however, no provision for relative speed variation among the twenty-four main drier rolls, which are geared together in two groups of twelve and driven by two motors mechanically load-coupled. The speed of the first motor is accurately controlled in speed by one of the eight regulators and the second motor follows it.

Derivative control

Each differential unit forms part of a *differential regulator* which includes a dashpot to provide an additional change in resistance of the carbon-pile regulator proportional to the time-derivative of the screw-shaft's linear movement. This provides derivative control on the system which increases the rate of response and decreases the amplitude and duration of a speed error. It may be noted that since it is angular positions that are compared, no permanent difference in speed between the driven and master motors is required to compensate for a permanent change in load conditions; all that is necessary is an angular lag between the rotors of the two motors. There are of course eight differential regulators, one for each motor whose speed is controlled; these are all the same, except that three different ratings of carbon-pile regulator are used according to the size of motor. The differential regulators are mounted in line on a framework in the control room; in the centre of them is the master motor with an output shaft extending each way into the regulators; and below the regulators and linked to them by the cone pulleys and belts are the eight synchronous motors. The speed of the master motor and the output voltage of the motor-generator are both stabilized by oil-servo-type regulators. The control room also includes the main 1000 kW motor-generator set, with a maximum voltage output of 550 V; a 60 V 1000 A crawl generator for use when starting the machines, owing to the high inertia of the rolls; a switchboard; and starting and control gear.

Harland Drives Ltd supplied the sectional electric speed interlocked drive for the machine. The electrical machines were manufactured by the Harland Engineering Co Ltd, and the differential regulators by Harland Drives Ltd. The main drive switchboard was supplied by Vlasto Clark and Watson Ltd and the Power Plant Co Ltd manufactured the in-drive gear units. The manufacturers of the machine itself were Millspaugh Ltd; and Black Clawson International and Foxboro-Yoxall were responsible for the process control equipment, which is not described in this article.

PICK-OFF

by
'UNCONTROLLED'

SPEAKING at the opening of the new Evershed and Vignoles offices last month, Sir Christopher Hinton said that he believed that obstacles to the further development of process control in industry would be as much psychological as technical or economic. 'I am quite certain,' he said, 'that technically there would be no difficulty within the next few years in putting chemical and other process plants under centralized control where the plant could be looked after virtually by one man . . . I believe that technically it would be reasonable to contemplate the time when all power stations could be operated from a central point. But in all of this, one has to remember that automatic controls today, and I think for a long time in the future, will look after the plant when it is operating normally or within certain narrow limits of departure from normality, and that when through some abnormal circumstance the plant runs beyond those limits, you have got to have a skilled man there . . . ' The problem, thought Sir Christopher, was how the plant operators are to be kept mentally alive during 99 pc of the time when the controls are looking after the plant so that they may respond during the remaining 1 pc of the time when the conditions are abnormal.

Clearly, as industrial plant becomes increasingly automatic, the operators left become more, not less, important, since more is at stake on their emergency reactions. Talking this over at the excellent buffet luncheon which followed the office-opening ceremony, I learnt that Sir David Mackworth was making much the same point in his opening 'guest leader' for CONTROL. Later I read Sir David's stimulating article (which appears elsewhere in this issue), and I was glad to see that Sir David's views on human observations did not lead him to suggest any deceleration in process control development. Rather he suggests that the phenomenon of a long period of normal control activity inhibiting abnormal control procedure should be seriously investigated. The industrial psychologist, human engineer, or ergonomicist, would presumably be the right specialist to make the investigation. I suspect his findings would show that some operators are stimulated by an emergency to act decisively; generally people either rise or fall to the unexpected occasion.

Meanwhile is it presumptuous to emphasize to plant engineers the value of practice, if they are worried by the possible consequences of faulty reactions by operators? After all the problem is not new. It is one that faces fire brigades, first-aid teams and especially the Fighting Services in war time. Dawn action stations might not be popular in the Isle of Grain, Bankside or Billingham as a regular event, but an occasional damage control exercise should have the right effect on the it-can-never-happen-to-me type of operator.

I believe it is quite wrong that most editors of technical journals hardly dare to mention advertisements in their leading articles. Everyone of course knows the essential part advertisements play in the economy of unsubsidized periodicals. But apart from this, publishers, editors and readers hold all shades of opinion on their value: from that which treats advertisements as a necessary evil to that which makes them the sole reason for a journal. Very few technical journals achieve a position where most of their readers consciously turn to the advertisement pages for information. But that is how it should be. For, neglecting profit and loss, technical advertisements have an essential and irreplaceable part to play in any journal serving an industry. To produce such a journal without advertisements would not be to play Hamlet without the prince but it would change the walls of Elsinore from stone to ivory. Advertisers (if they are wise) will not accept instructions from an editor, any more than an editor (if he is reputable) will have the contents of his own pages influenced by advertisers' requests. But for what a columnist's view is worth, my feeling is that advertisements in CONTROL should be technically informative without being dull. Most commercial and technical staff in engineering firms like to acquire a few technical facts, when their eyes are caught by a compelling slogan or layout.

THE editor tells me that a near miss for the title of this journal was *Control Systems Engineering*. In fact it seems that only the reasoned intervention of one of their editorial consultants persuaded the publishers and him that CONTROL was *the* title. Purists might object to CONTROL as a title on the grounds that it is vague, and does not indicate what sort of control it covers. But surely a journal title—even a technical one—need not be definitive?: what is important is that its readers should recognize it and know what it stands for. Anyone who has bought this issue expecting to read about birth, pest, self or traffic must have been quickly disillusioned, even if he did miss the subtitle on the front cover. Did *Punch* get a few boxing enthusiasts among its early readers 117 years ago?

Certainly CONTROL is easy to remember and to use; one-word titles often have an inherent appeal and it is, I think, already taking a place among the other one-word titles of the scientific and technical Press—*Discovery*, *Endeavour*, *Engineering*, *Nature*, *Research*, *Technology*, etc—which are widely recognized and remembered. Moreover, CONTROL's readers should be grateful for their reprieve from having to twist their tongues over 'Control Systems Engineering'. Another candidate for the cover page was 'Systems Engineering' alone. I am never happy about this phrase, quite apart from its merits as a title. 'Control systems engineering', 'Television systems engineering', 'Communication systems engineering', yes—but the bare 'Systems engineering', no. It seems too vague for defining the practice of a particular breed of engineer. Most of us are 'systems engineers'—or we should be. But usage—and especially American usage, which so often leads ours in new thrusts of engineering activity—is a powerful weapon in terminological struggles. 'Systems engineer', is, I think, used more on the other side of the Atlantic than here, and one cannot deny that it now has a useful connotation—of an engineer with a strategical rather than tactical outlook. Moreover the influence of 'cybernetics and all that' is to open up applications for engineering systems that involve, perhaps control, communication, computer radar and television engineering all at once. At any rate we shall in the future almost certainly require more engineers in the light electro-mechanical field who appreciate the grand design. In talking recently with a control systems engineer in a large industrial firm, I was struck by his remark that the emphasis of the systems engineer should be on synthesis from existing hardware rather than design of ideal control systems. As all design engineers, control systems engineers must often find economic efficiency and technical efficiency pulling in opposite directions. Experience and intuition are likely to be at least as useful as analytical ability in designing to satisfy the customer's needs and his pocket.

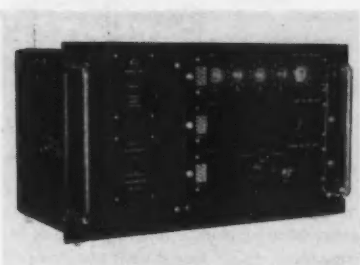
I WAS excited to see that the principal subject of correspondence in this month's *Technology* is control engineering; two longish letters from Sir Walter Puckey and Professor A. Porter provide admirable mental stimulus for anyone thinking about the training of control engineers. The correspondence has been sparked off by Sir Harold Hartley's challenging address to the SIT. The main point at issue is the prickly one of primary and secondary technologies—one which I shall not discuss here because I do not know a good definition of 'primary technology'. But another point in Sir Harold's address which whetted my curiosity was his reference to the founding of a Chair of Control Engineering at McGill University, Montreal. So far as I can discover, this Chair is the first in the English-speaking world to be specifically styled 'control engineering'. Sir Harold posed the question 'Which British university will be the first to establish a similar Chair?' Which indeed? My guess would be London.

NEW FOR CONTROL

A monthly review of system components and instruments

RPM by electronics

The Dowty electronic tachometer Mk IV utilizes digital counting techniques for the measurement of shaft speeds with refined ($\pm$ 1 r.p.m) accuracy. Specially designed for incorporation in gas turbine test-bed consoles, it features a remote display head and remote switching unit. For laboratory or portable use these remote units can be mounted in the main body of the equipment. The construction and component layout allow the equipment to be adapted to suit particular requirements, and versions



Electronic tachometer

are available catering for time measurements and speed ratios in addition to the normal tachometer functions. Front panel switches and knobs have been kept to a minimum to ensure easy operation. Front panel sockets provide for voltage and current checks, and a switched test meter unit is available. Transducers are available which use the electrical output of the tachogenerators normally fitted to gas turbines, thus enabling the tachometer to be installed and operated without modification to the gas-turbine or auxiliary equipment.
Tick **No 91** on reply card

Ice warning on aircraft

Any part of an aircraft where a pressure drop occurs (as in the air intake of an axial flow jet engine) may suffer from icing conditions even though the surrounding temperature is above freezing point. If this ice is allowed to build up it may break off, enter the intake and damage the engine; or it may make the aircraft difficult or impossible to handle. The formation of this ice is dependent upon the presence of free water in the atmosphere and of a local temperature below freezing point. In the Sangamo Weston ice-warning system, measurements of these conditions are fed to a control unit, which on the formation of dangerous conditions will initiate an alarm or de-icing equipment or both. The system is composed of three basic units, the resistance bulb, the detector head and the control unit. There are two control units available, one which needs manual resetting when icing conditions are no longer present, and the second which resets automatically. The equipment has been designed in conjunction with the Ministry of Supply and Royal Aircraft Establishment.
Tick **No 92** on reply card

High speed switching

A life in excess of 100 hours at 6000 r.p.m is given by Vactric (Control Equipment) Ltd for their 80g high-speed rotary switch. The wiper pressure is low, compatible with contact wiper bounce, so that several banks may be ganged together using the 1 in. diameter motor. The efficiency of the switch in h.f. systems is ensured by the low coupling between switch segments. It has been used for d.c. signal chopping, waveform generation, amplifier stabilization, low-level sampling of strain gauges and thermocouple signals and in other ways. If a precision gearhead is fitted the range of high-speed switches can be converted to low-speed switches.
Tick **No 93** on reply card

High performance midget motor

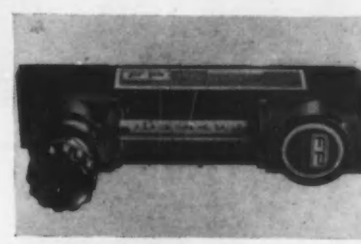
An addition to their range of small, low voltage, high performance, permanent-magnet motors has been made by R. B. Pullin & Co Ltd. The newcomer is the type PM18, available at a standard voltage of 28 V d.c., governed or ungoverned, in the international size 18 mounting. The motor can also be supplied in type 18PMT, a high-sensitivity, low-ripple d.c. tachometer generator with a rated output of 16·7 V per 1000 r.p.m. and maximum linearity error at 5000 r.p.m. of 0·1 per second.
Tick **No 94** on reply card

Seal by Trist

A new design of seal, the SEATRIST SCN-Ring, for use in reciprocating hydraulic mechanisms, is now in full-scale production after extensive laboratory and field tests. The design uses a sealing element of smooth, oil-resisting synthetic rubber bonded to two concentric backing-rings of tough laminated fabric. This feature causes the fluid pressure to be transmitted radially to the backing rings so that they react instantly to changes of pressure and to small movements of the sealing surfaces caused, for example, by side thrust or cylinder bore swell. As a result, the sealing lip and body are always fully supported and protected against extrusion wear. The SCN-Ring is manufactured by Ronald Trist and Co Ltd and can be used both for piston head and gland sealing. It is a complete, single unit seal and does not require special adaptor or header rings. Seal housings are of a simple non-adjustable type. The seal is in service at pressures up to 10 000 lb/in^3 and is available in over 50 standard sizes from $\frac{3}{8}$ in. to $9\frac{1}{4}$ in.
Tick **No 95** on reply card

Variable-area flowmeter

Fischer and Porter Ltd have announced the addition of models 1115 and 1120 Purgerator meters to their flowmeter range. The Purgerator is claimed to be completely new in the United Kingdom. It is a reduced



Purgerator

accuracy, indicating variable-area flowmeter, produced primarily for controlling the flow of gases and liquids at a constant rate for bubbler service applications and purging operations, as with corrosive service manometers. It can also be used in conjunction with the Fischer and Porter constant differential-pressure regulator for measuring liquid level in an open tank.
Tick **No 96** on reply card

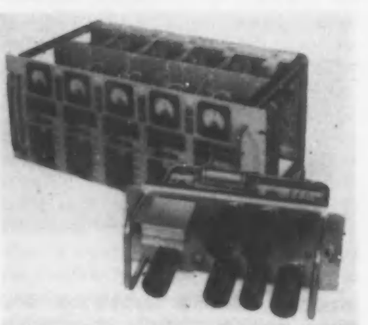
Automatic titration

The Analamatic Auto-Titrator can be used for measurements requiring a titration where a potentiometric, pH or dead-stop endpoint is needed. This apparatus is fully automatic and is manufactured by Baird and Tatlock (London) Ltd. The potential produced by two electrodes immersed in

the solution being titrated is amplified and compared with two pre-set values. Titrant is added continuously until this potential reaches the first value (arranged to be slightly before the end point), and then by drops to the end point. An automatic solenoid-operated valve is used to control the addition, and the drop frequency may be adjusted over a wide range. False end-points before the true one are avoided by a delay system in the control unit. When the true end-point is reached the burette is read automatically by a photo-electric meniscus-follower system and the result is printed on a paper strip. This result may be in any convenient system of units, the necessary calculation from volume to the final answer being allowed for in the instrument.
Tick **No 97** on reply card

Computing components

A new computing amplifier by Saunders Roe Ltd has a number of advantages over the previous model, including its increased electronic performance and its more compact form. The unit has been designed primarily for use in high-accuracy, slow-speed d.c. analogue computers but would be suitable for use in computers employing repetitive operation. The main d.c. amplifier is corrected for drift by a chopper a.c. amplifier and is capable of establishing a voltage of $\pm$ 50 V in a 5 kilohm load or of providing a current output of $\pm$ 10 mA.

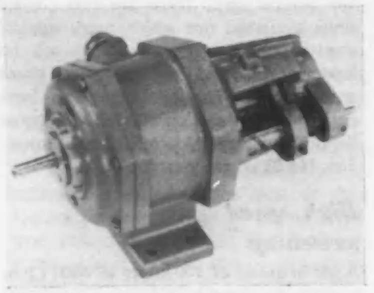


Amplifier and panel

A mounting panel has been designed in conjunction with the computing amplifier to provide a convenient mounting for five amplifiers. The front panel carries five groups of colour-coded patch-panel sockets, five amplifier output meters and five overload neon indicators. Each group of sockets comprises sufficient sockets permanently connected to the respective amplifier mounting to carry the computing impedances forming the problem set-up. In addition, each group has an 'initial condition' socket for use when an amplifier is being used as an integrator and sockets to carry the incoming $\pm$ 50 V 'machine units'. A second panel behind the first carries ten relays, two per amplifier, to connect the amplifiers into any of three states, 'rest', 'compute' or 'hold'. The relays are controlled remotely by a control unit.
Tick **No 98** on reply card

Nash and Thompson multiplier

A robust, eletromagnetic computer for multiplying two independent and variable analogue factors has been manufactured by Nash and Thompson Ltd. It is essentially an a.c. tachogenerator in which the flux



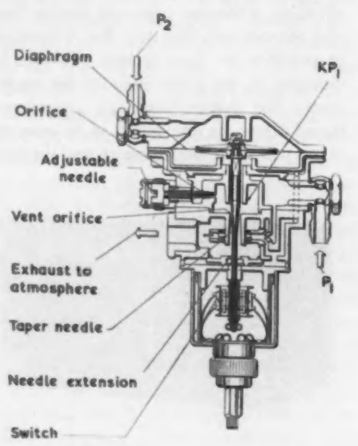
Electromagnetic computer

influencing the stator coils can be varied from zero to a predetermined maximum by the first variable through a linear movement. The second variable is speed of rotation of the shaft and the computer will indicate on a meter the product of the shaft speed and linear movement of the rotor with a sensitivity of 0·001 of either variable. The present unit has a speed of rotation of 0–300 r.p.m, linear movement range of 0–1 in. and a maximum output of 50 volts. The first model has a linear displacement characteristic but by suitable design of the magnetic circuit a non-linear function can be used.
Tick **No 99** on reply card

Pressure ratio control unit

The Microjet is a comparatively simple device that gives an output proportional to the error between the measured and the required pressure differential in a fluid. It is completely independent of the absolute value of the pressures used and has a negligible time delay. The drawing shows the Microjet in its simplest form. The larger of two pressures P_1 is fed via a fixed orifice to a compartment on the needle side of the diaphragm, and is vented to atmosphere by a second orifice controlled by the taper needle. The reduced pressure between these two orifices is a reference pressure KP_1, and is a predetermined fraction of the original pressure. The predetermined value of K depends upon the position of the needle in the first orifice. The reference pressure is equated through the diaphragm to a second pressure P_2, which means that, when the taper needle is in its datum position, the pressure P_2 is a predetermined fraction of P_1 and any deviation from this desired ratio causes the outlet needle to move an amount proportional to the error. In the drawing the needle is shown operating an electric switch but it could be equally well a hydraulic or pneumatic pilot valve. There are a number of refinements in the Microjet to maintain its accuracy when the fluids are at high temperatures. If liquids or toxic gases are used then it would not normally be possible to discharge directly into ambient air.

The Microjet has had a number of uses in the aeronautical field, including the indication of oblique and normal shocks in supersonic air intakes, the operating conditions of air compressors and gas



Section through the Microjet

turbines and for the control of variable reheat systems. A possible industrial, use would be in the mixing of two fluids in a fixed proportion at varying flow rates. Whatever the flow rate the pressure differences across an orifice in each of the fluids should remain in the same proportion. If these pressure differences were fed to a Microjet it could be employed to control a proportioning device.

The Microjet pressure ratio control unit is made in this country by H. M. Hobson Ltd under licence from the Solar Aircraft Company of America.
Tick **No 100** on reply card

Plessey infra-red detector

An infra-red cell employing the 'photoelectromagnetic effect' in a crystal filament of indium antimonide has been marketed by Plessey. The crystal filament ($3 \times 1 \times 0{\cdot}02$ mm) is mounted in the gap of a small permanent magnet and housed in a case with an opening over the element. The action of radiation is to produce electron-hole pairs near the front surface of the material and the resulting concentration gradient produces diffusion towards the back surface. The transverse magnetic

field separates the charge carriers, so obtaining a signal voltage across the end contacts. The cell has a resistance of between 10 and 100 ohms and a time-constant of less than one microsecond. At room temperature the sensitivity is uniform between 2 to 6 microns with a cut-off at 7 microns. The cell is influenced by static magnetic fields so that care must be given to the mounting if this property is not required.
Tick **No 101** on reply card

Level control by capacitance

The Proxicon Mk III is a capacitance-type industrial level controller which has no contact with, or moving parts in, the liquid or free-flowing solid to be controlled. This model replaces the Mark II and can be supplied by J. Edward Hall (Elec. Engineers) Ltd for single- or dual-level applications in three voltage ranges. A trigger circuit ensures rapid action of the switch even with a slow capacitance change, due to slow movement in the material level. Remote control can be extended up to 3000 ft by the addition of tapped electrode terminals.
Tick **No 102** on reply card

Sub-miniature connectors

A range of sub-miniature coaxial plugs and sockets has been designed by Belling & Lee Ltd to meet the requirements for connectors in miniature equipment. The plugs are suitable for use with coaxial cable having an approximate outside diameter of $\frac{1}{16}$ in. The insulation is of p.t.f.e. (polytetrafluorethylene) to ensure low high-frequency losses and a high maximum working temperature. The contact surfaces are gold-plated.
Tick **No 103** on reply card

Automatic photographic processing

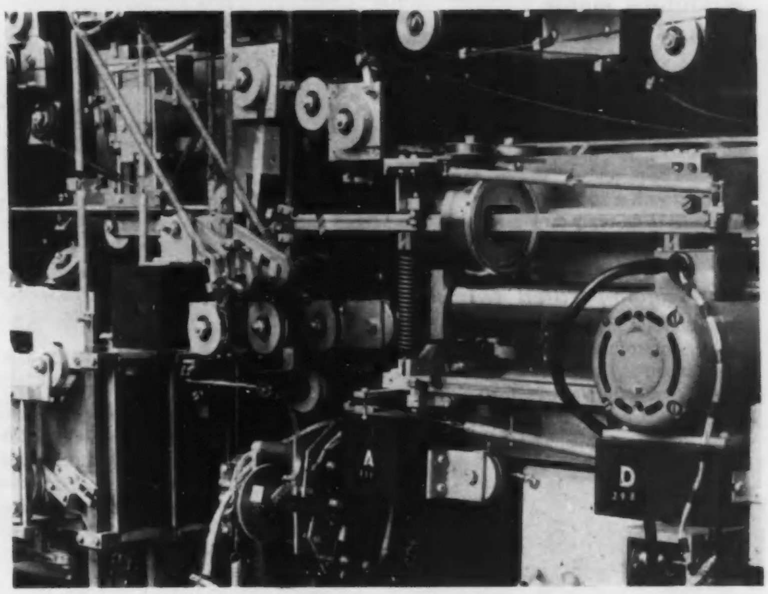
A mains-operated processing machine, suitable for processing all types of photograph paper normally used in galvanometer and oscilloscope recorders can be supplied by New Electronic Products Ltd. The paper is automatically passed through separate containers containing developer, fixer and water. There are speeds of $\frac{1}{4}$, $\frac{1}{2}$, 1 and $1\frac{1}{2}$ in. per second to provide for different papers and exposures. The equipment is fully automatic, portable and has been designed in conjunction with the Royal Aircraft Establishment, Farnborough.
Tick **No 104** on reply card

Kent two-phase servomotor

A two-phase servomotor by Kent has a built-in tachogenerator for providing feedback signals. The rotor is of the squirrel cage type and the whole unit is sealed with the reduction gear train in its own oil supply. The high impedance of the windings makes them suitable for direct connexion to the output stage of a thermionic amplifier. The power winding is supplied from 110 volts a.c. 50 c/s through a capacitor.
Tick **No 105** on reply card

Computer kit aids construction

A comparatively inexpensive kit for the construction of mechanical computers can be supplied by Air Trainers Link Ltd. The basic kit contains a double integrator, two multipliers, four summing levers and a number of pulleys, stands and fittings for



Section of a 'Dart' simulator

assembling the parts onto a base plate. The assembly can be rapidly finished without any special facilities. The basic kit could be used to build, among other things, a computer to solve a linear second-order differential equation. If more complex computers are required then it is possible to obtain larger kits or individual components. An example of an elaborate computer which has been built up from these kits is given in the photograph. This shows a section of one of four mechanical computer systems, each one of which will reproduce the characteristics of a Rolls-Royce Dart aircraft engine. The four systems are part of an Air Trainers Link Viscount 'type trainer' in which both pilot and co-pilot can be trained in the correct handling of the aircraft.
Tick **No 106** on reply card

Nylon couplings for hoses

A useful hose coupling that eliminates the need for permanent fittings on the end of the hose is manufactured by Airtech Ltd. One of these couplings can be fitted securely to the end of an unprepared hose by hand, and removed as often as required. The coupling is made of nylon and is complete in itself. It is suitable for compressed air and fluid working pressures up to 250 lb/in^2 and is available in two types. The first is used for joining two lengths of rubber or plastic hose together. The second is for permanent installation to a tool or supply point and has one end threaded, and the other end free to accept a hose which can be locked in place by hand. The nylon couplings can be supplied in 5 sizes for hose inside diameters of $\frac{1}{4}$ in. to $\frac{3}{4}$ in.
Tick **No 107** on reply card

Latch addition to relay

A 3000 type magnetic relay can be fitted in less than a minute with a device made by Jack Davis (Relays) Ltd for latching the relay after energizing. The relay can be released by a push button above the latch or by an extended cable.
Tick **No 108** on reply card

Smoking alarms

A smoke alarm suitable for chimneys up to 15 ft in diameter can be delivered by Photo-electronics (MOM) Ltd. A light source projects a beam across the chimney onto a cadmium photocell housed in a receiver unit. The photocell converts the light into electrical energy and as smoke breaks the beam a varying current is emitted by the cell. This current is sufficient to operate a relay directly, and when the smoke has reduced the current emitted by the cell to a

point set by the operator, the relay closes and the alarm is given.
Tick No 109 on reply card

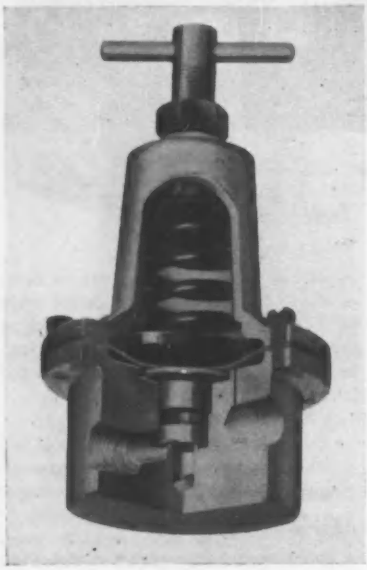
The same firm has a smoke density indicator which is suitable for chimneys up to 40 ft in diameter. It operates on the same principle as the smoke alarm but the varying current from the cadmium photocell is shown on a 10 in. scale meter calibrated in percentage of the chimney obscured. A recorder can be supplied to give a permanent record of the smoke condition and both visual and audible alarms are fitted.
Tick No 110 on reply card

Muirhead miniature motor

A size 08 servomotor with an overall diameter of 0·75 in., a length of 0·96 in. from the front face to the ends of the connexion tags, and a shaft extension of 0·16 in., has been produced by Muirhead and Co. Ltd. It has a no-load speed of 6500 rev/min and a stalled torque of 0·1 oz-in. with a 26 V 400 c/s supply.
Tick No 111 on reply card

Safety lock for diaphragm-operated valve

A lock-up valve which will lock a diaphragm operated control valve in the position it was at the time of an air failure has been manufactured by Crosby Valve & Engineering Co Ltd. The Mason Neilan type 76 lock-up

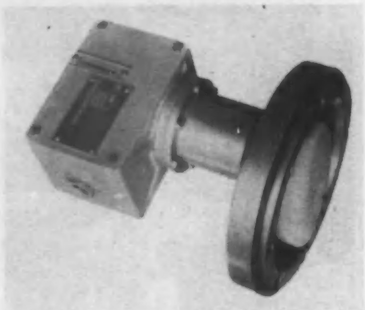


Crosby valve

valve is connected between the control point and the diaphragm connexion of the control valve. During normal operation the spring is compressed by the control pressure and allows an unrestricted output to the diaphragm of the control valve. If the control pressure drops below a pre-determined value, the spring moves the soft-seated plug downwards, locking the last control pressure in the diaphragm case of the control valve. Provided that the air-line connexions are sound, the lock-up valve will maintain the control valve in a fixed position. The rating of the valve has a range of 10–40 lb/in² which enables the valve to be pre-set to lock at any required air failure pressure within this range.
Tick No 112 on reply card

Londex alarm and controller

A rotation sensitive device made by Londex Ltd provides an alarm on the stoppage of



Level controller for solids

rotating machinery used for continuous processing. The drive to be monitored is fitted with one or more cams which cause the follower arm to be lifted once or more during each revolution. An alarm is sounded between 2 and 6 sec after the drive ceases to rotate. The standard unit is for a range of 30–300 r.p.m but this can be extended.
Tick No 113 on reply card

Another device by the same company will operate contacts if the level of material in a bunker reaches a predetermined value. It has been designed for heavy and abrasive materials, and will operate in bunkers handling 5 in. raw material. A pressure pad projects into the bunker and is attached at its base to a thick rubber diaphragm. Material pressing on the pad will actuate a bellows-operated pressure switch through a brass tube filled with ethylene glycol. The silver, single pole, double throw contacts are rated at 5 amp 250 V a.c. or 3 amp 440 V a.c.
Tick No 114 on reply card

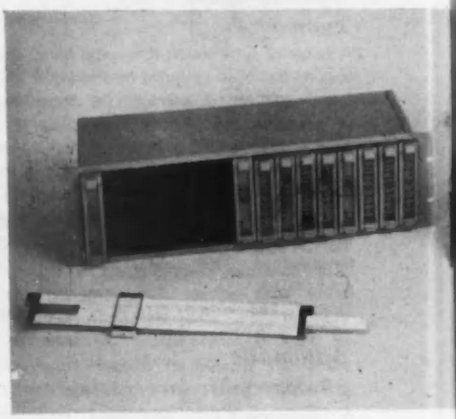
Adding and subtracting

A six-figure high-speed electric counter has been introduced by Counting Instruments Ltd. The operating speed is at least 20 counts per second and the consumption is 5 W. The number wheels and associated pinions are constructed from low-friction nylon and this assembly is actuated by a balanced escapement system set in jewelled bearings. The movement is operated by two electro-magnets and is available for a.c. or d.c. supplies. Instantaneous reset is obtained by deflexion of a short lever.
Tick No 115 on reply card

The same company has also introduced an add and subtract counter. The five-figure display is actuated by two escapement-type mechanisms operated from separate d.c. or a.c. supplies. The first escapement operates to add, and at the same time releases the second, and when subtracting this procedure is reversed. Counting is possible up to 17 counts per second.
Tick No 116 on reply card

Digital building blocks

Special test equipment or complete digital systems can be quickly and easily assembled using the high-speed (5 Mc/s) transistor building blocks produced by Harvey-Wells Electronics. These Data Blocs are joined together by pin-jacks and can be used to build shift registers, counters, pulse generators, pattern generators, etc. It is possible to produce permanent equipment from the Data Blocs by specifying and employing



Data Blocs

Data Pacs, which are the printed circuit plug-in cord equivalent of the Data Blocs.
Tick No 117 on reply card

Moiré fringes in resolver

An optical resolver that employs two circular diffraction gratings has been shown by Hilger & Watts Ltd. One of the gratings is on a shaft and the other is fixed but close to the first. As the radial rulings on the gratings are not quite parallel a moiré fringe can be seen. If the shaft is rotated the fringes move up and down the ruling and the angular displacement of the shaft is measured by counting the fringes. The fringes are detected by two phototransistors positioned so that their approximately

sinusoidal outputs are roughly 90° out of phase. In this way it is possible to distinguish between clockwise and anticlockwise rotation. A discriminator accepts one phase for clockwise counting and the other phase for anticlockwise. A third detector provides a reference mark on the scale. In this way the optical resolver can be used as a pulse generator and a direction indicator. The inertia of the resolver is that of a thin glass disk of small diameter and the torque required is less than 1 oz–in.

Tick No. 118 on reply card

Another addition to the products of this company is an optical digitizer. The digitizer is a coded commutator using light and photocells instead of electrical contacts. The following advantages are claimed over mechanical models:

1. The torque is lower owing to the absence of contacts on the disk.
2. The life is longer as the mechanical wear is limited to the ball bearings.
3. For the same resolution the diameter is smaller.

Tick No 119 on reply card

PEOPLE IN CONTROL

Mr Sebastian Z. de Ferranti succeeded Sir Vincent de Ferranti as Managing Director of Ferranti Ltd. Sir Vincent resigned in favour of his eldest son, but remains Chairman of the company.

Fisher Governor Co, a member of the Elliott-Automation Group, announce the appointment of **Mr J. R. Moore** as a Director.

Dr L. L. Ross has been appointed Deputy Managing Director of Elliott Brothers (London) Ltd. **Rear-Admiral Sir Alexander D. McGlashan** and **Mr J. E. O'Breen** have been appointed Directors of the company.

The Plessey Co Ltd announce that **Mr Andrew M. Brown** takes up his duties as Executive Director on 7th July. His special responsibilities will be as Personnel Co-ordinator.

Belling & Lee Ltd announce the appointment of **Mr C. F. Greenwood,** until recently Scottish Area Manager of EMI and Marconiphone, as representative for Scotland and Northern Ireland. He succeeds the late Mr Ian G. D. Boyd.

Brigadier A. Levesley, a Director of Edgar Allen & Co Ltd, has been appointed President of the Sheffield and District Engineering Trades Employers' Association, in succession to **Mr Ambrose Firth.**

Mr R. E. Burnett, General Manager of Marconi Instruments Ltd, and **Mr S. G. Spooner,** Production Manager, returned on the 25th June from a three-week marketing tour in the USA. Discussions were held with executives at the company's new premises in Englewood, New Jersey, and comparisons made between US and British manufacturing techniques.

Mr J. F. Coales took office as President of the Society of Instrument Technology for 1958–59 on the 2nd June. **Mr G. C. Eltenton** and **Mr R. S. Medlock** have been appointed Vice-Presidents.

Mullard Ltd have formed a new division, embracing the former communications and industrial valve department and the government radio valve department, under the management of **Mr H. St A. Malleson.** In this division will be four individual product groups, each in charge of a commercial manager: electron optical devices—**Mr J. V. S. Tyndall;** receiving valves—**Mr R. Robinson;** special industrial valves—**Mr K. F. Gimson;** transmitting and microwave valves—**Mr P. S. Britton.**

EMI Electronics Ltd have appointed **Mr R. W. Addie** to the Board as Marketing Director, after six months' service with the company as an Export Manager. His responsibilities will be the commercial sales activities and policies at home and abroad.

Mr Robert L. Lickley, Technical Director of the Fairey Aviation Co, has relinquished his second post of Chief Engineer. **Dr G. S. Hislop,** formerly Chief Designer (Helicopters) is appointed Chief Engineer (Aircraft), and will be in charge of all design, technical office, drawing office and laboratory work. **Mr L. R. E. Appleton** (formerly Head of Guided Weapon Design and Development) is appointed Chief Engineer at the Heston works, being responsible for design and development on guided weapons, nuclear engineering and electronic instruments.

Professor J. L. M. Morrison, Professor of Mechanical Engineering at Bristol University, has been appointed Chairman of the Advisory Council on Scientific Research and Technical Development to the Minister of Supply, in succession to Sir Eric Rideal, who had been Chairman since 1953. The following have been appointed to the council: **Sir William Cook,** Member of the Board of the UKAEA for Engineering Production; **Sir Ian Heilbron,** lately Director of the Brewing Industry Research Foundation; **Professor W. T. J. Morgan,** Deputy Director of the Lister Institute and Professor of Biochemistry, London University; and **Professor N. F. Mott,** Cavendish Professor of Applied Mathematics at Liverpool University.

Mr MEDLOCK

Mr de FERRANTI

Mr COALES

Mr ADDIE

Mr MALLESON

Mr BROWN

From the BIRTHDAY HONOURS LIST

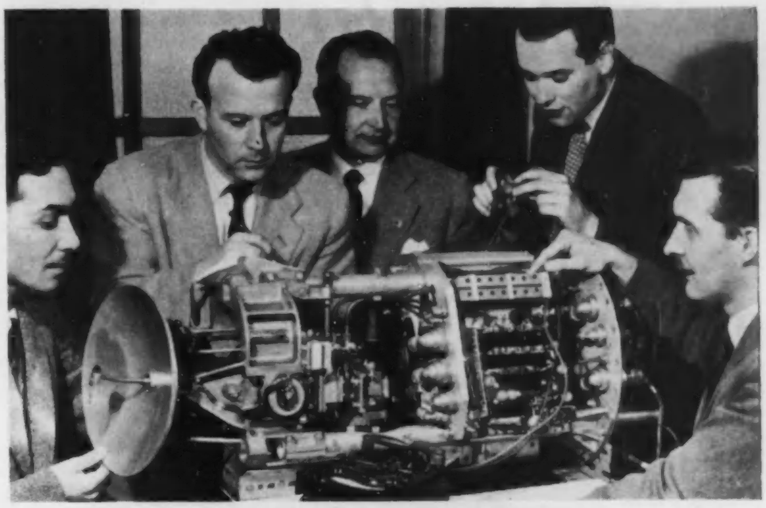
Dr Willis Jackson, Director of Research and Education, Metropolitan-Vickers Electrical Co—*Knight Bachelor.*

Mr Morien Bedford Morgan, Deputy Director, Royal Aircraft Establishment—*C.B.*

Dr Eric Stanley Moult, Director and Chief Engineer, de Havilland Engine Co—*C.B.E.*

NEWS ROUND-UP

.. FROM ALL SOURCES



CRANFIELD MISSILE COURSE
Sent from widely scattered NATO countries to Cranfield for the second one-year guided missile course, Capt B. Ersever (Turkey) (left), Lt O. Linge (Norway), Major L. C. Leitao (Portugal) and Lt J. Danneels (Belgium) check out a typical homing head incorporating an Elliott scanner. Mr K. C. Garner (right) is lecturer in Control and Simulation for the College of Aeronautics course, which includes design, production and guidance. Laboratories are equipped with analogue computers, servos and measuring gear to provide first-class studies of feedback control systems

Piecemeal approach must go

It was an important occasion for the Society of Instrument Technology when Sir Harold Hartley delivered his Presidential Address recently. It was an important occasion too for control engineers in general, for this was probably the first time that a man of Sir Harold's authority has expressed such realistic and outspoken views about the future of control engineering in Britain. His address was entitled 'The Place of Instrument Technology in Control Engineering', but its scope was much wider than the title suggests: at the outset Sir Harold made his salient point that control engineering should now be included alongside civil, mechanical, electrical and chemical engineering as a primary technology. It was indeed inspiring to hear Sir Harold—officially retired many years ago, but always finding new activities on which to exercise his acute mind—taking up the cudgels for control engineering, when not so long ago he fought and won a similar battle for the recognition of chemical engineering in this country. Britain has very few scientists or engineers with his breadth of vision.

Sir Harold outlined the emergence of the present four primary technologies and mentioned the development of the secondary technologies covering special branches of industry. He recalled that Siemens in his presidential address to the British Association in 1882 forecast a great future for electrical engineering. In his view control engineering has reached a similar stage of development. The growth rate of the control engineering industry is probably greater than that of any other industry; recently in the USA the annual rate has been 20 pc.

Sir Harold cited the impressive contribution which the Russians have been making to the development of the theory of control engineering. They have recognized that it is a subject in its own right and not something to be added piecemeal to process and production engineering.

Two consequences followed from the recognition of control engineering as a primary technology. It must take its place as an independent academic discipline and the control engineer must be accepted as a member of a modern project design team. Control must contribute to the compromise that design ultimately represents.

Sir Harold continued by outlining the training required by a control engineer. The undergraduate should have the same grounding as any other aspiring engineering student in fundamental physics and mathematics during his first two years. In the second two years would come instruction in specialized aspects of control engineering. In addition there must, of course, be practical training in industry.

Electronic forum for industry

A new move towards helping industries through the growing complexities of electronic automation and computation was made recently with the setting up of a co-ordinating body to be known as the Electronic Forum for Industry. This followed talks between manufacturers' and users' organizations sponsored by the Data Processing Section of the Electronic Engineering Association. The aim is twofold: to provide a clearing house for exchange of information and to make available a channel for the presentation of the British industrial point of view in international discussions. 'The EFFI will not assume the work or responsibilities of the individual associations,' said Mr C. Metcalfe, Chairman of the EEA Data Processing Section, who presided at the first meetings, 'nor will there be any impingement on the work of the professional institutions'. So far discussions have been entirely on a technical level and it is hoped that the EFFI will lead to the co-ordination of technical committee work, research, development and application of new techniques in industry.

Organizations now taking part, besides the Electronic Engineering Association, are the British Electrical and Allied Manufacturers' Association, British Radio Valve Manufacturers' Association, Machine Tool Trades Association, Society of British Aircraft Constructors, Telecommunications Engineering and Manufacturing Association, Radio and Electronic Component Manufacturers' Association, Office Appliance and Business Equipment Trades Association and Scientific Instruments Manufacturers' Association.

IFAC starts work

The International Federation of Automatic Control founded in Paris last September has now started work. Following a recommendation of the executive council under the President, Mr H. Chestnut (USA), member organizations have been asked to approve the establishment of three main committees—for automatic control theory, components and measurements, and applications. Replies are due in by the 24th of July and the next step will be to choose a chairman for each committee; the secretariat is to be offered to one of the member organizations. These total thirteen so far, including five from the communist bloc. Countries represented are Austria, China, Czechoslovakia, Denmark, Italy, Japan, Norway, Poland, Rumania, Sweden, Switzerland, USA and the USSR. The British Conference on Automation and Computation is expected to join as soon as it receives the go-ahead from its Group C, the section concerned with sociological and economic aspects. Group A, on the engineering applications and Group B, on design problems, have already expressed willingness to join. Other

committees proposed by the IFAC Council, acting on suggestions by the Advisory Group under D. P. Eckman (USA), will work on bibliography, nomenclature, symbols and definitions, and educational questions.

Away from control

An inside look at the workings of BBC Television and a visit to the Electricity Council Training Establishment at Horsley Towers were the main items chosen for this year's summer outing of the IEE Measurement and Control Section. About a hundred members, including the chairman, Mr H. S. Petch, and Dr Denis Taylor, one of CONTROL's editorial consultants, inspected the Television Centre and the Lime Grove and Riverside Studios. Later the party went to look at the supply industry's training school, which now trains over 3000 members of the industry each year; ground covered ranges from technical courses for manual workers to training for executives.

. . FROM INDUSTRY

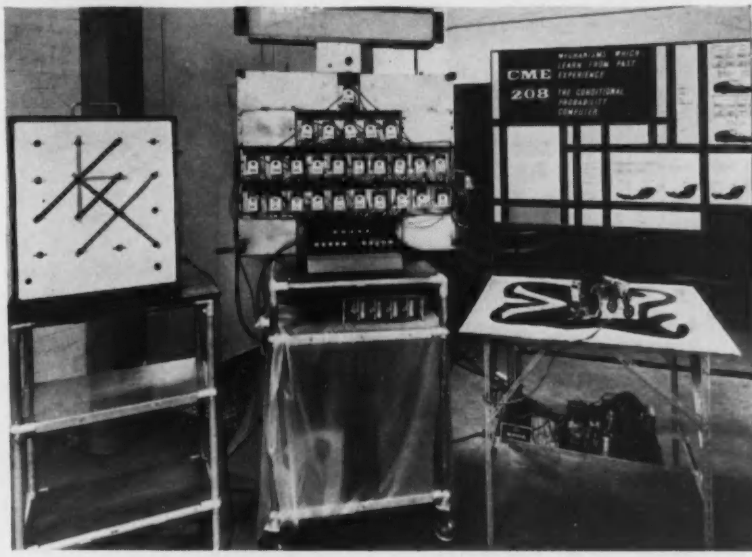
OIL

NPL device to 'learn' control

The swing away from the design and construction of computers to the study of 'learning' machines which is in progress at the National Physical Laboratory should be encouraged and increased, says the executive committee in its annual report. Believing that 'important economies' in industry lie in this direction the committee stresses the 'imperative' need of a new building and a 100 pc increase in staff for the Control Mechanisms and Electronics Division.

The first practical application of the NPL's work on learning theory may be in the oil industry, and it was recently revealed that the Division is in touch with British Petroleum on the possibility of constructing a machine for a complex control problem in the company's South Wales refinery. This move follows promising results obtained from the conditional probability computer (CPC) built for Dr A. M. Uttley, who is now head of CME Division. It can determine, on the basis of its stored statistical information, whether activity in one group of the input channels is usually accompanied by activity in other channels. If it is, the computer makes an 'inference' of activity in the other channels. To ensure that the inferences are governed by the most recent events, the charge on a condenser, which represents the total number of events, is deliberately made to leak towards the level corresponding to zero count.

'The CPC is of interest in two connexions' says the responsible officer, Dr A. M. Andrews. 'It imitates certain features of animal learning and also illustrates principles which we hope to incorporate in 'learning machines' having industrial applications. The idea is to control a process by a machine which modifies its control function as a result of trial-and-error experimentation and so learns to control the process more and more efficiently. Such a machine should be useful where the process is too involved to be analysed mathematically.' A learning machine suitable for process control will be considerably different from the existing CPC; for one thing its input channels will carry quantitative information regarding flows, temperatures, etc instead of simple yes–no signals. The Division is working on the problems involved and some results will be disclosed in the symposium on 'The Mechanization of Thought Processes' which is to be held at the NPL in November.



This 'learning' computer, developed by the NPL, can instruct the Meccano trolley, which is fitted with a lamp and two phototransistors, to search its way round the black-white boundary of the pattern. If the trolley steering linkage is reversed, the computer makes consistently wrong inferences at first, but eventually relearns under — the new conditions

AIRCRAFT

Germans to use British autopilot

A British automatic pilot will be used on the Nord Noratlas 2501 military transport which is to be built for the German Air Force by Flugzeugbau Nord GmbH. Following a study of automatic pilots from manufacturers on both sides of the Atlantic the field narrowed to the Smiths SEP2 and flight trials were held recently at the main Nord Aviation private airfield in France. These lasted 21 hours and included runaway tests, performance assessments and tests for certification of safety. As a result the installation was cleared for production aircraft and has also been specified for Noratlas aircraft destined for civil operators.

The SEP2 is already in use on several British and overseas airlines and will be fitted to the new BOAC Comet IV jet airliners. In addition to stabilizing the aircraft it provides for monitoring from either half of a twin compass system (including the preselection of heading when required), height and airspeed locks, coupling to selected VHF radio beams, and enables automatic approaches in adverse weather to be made in conjunction with the radio approach aid. In the installation planned for the Comet IV a yaw-damper will be included with the aim of improving general handling.

Complementing the automatic pilot on the Comet IV will be the Smiths Flight System. Features of this are instruments using remotely mounted attitude and directional gyros to give information on pitch, bank, and the navigational situation, relating heading to radio track displacement; these are supplementary to the instrument which provides bearing intelligence in relation to the heading of the aircraft and to the usual indicators for speed and height etc. A new method of controlling the erection signals on the gyro verticals is hoped to keep errors due to turning flight down to below 1° on the Comet IV.

First on the shop floor

Programmed from punched tape and working a double-shift 16-hour day directly on the production floor for five months, an electronically controlled machine tool has proved quite capable of standing up to the rigours of factory use, state EMI Electronics. The machine—a Cincinnati No 3 vertical mill fitted with an EMI control system—was installed by Short Brothers and Harland in one of their Belfast machine shops

last January. It is being used as an additional profile milling machine in an attempt to keep down the cost of turning out a variety of components needed only in small quantities—a major headache for aircraft manufacturers. Conventional methods of tooling-up for mass production in such cases are quite uneconomic, and electronically controlled tools have the added advantage that amendments to design drawings can be quickly incorporated into the control tape. Although machine tools fitted with EMI's control systems have been used for some time in specialized work this is believed to be one of the first employed on a production scale. It is a standard model with an analogue control system which dispenses with the need for an external computer to convert information from the drawing board to the punched tape.

The United States Air Force has become interested in EMI installations, and the first model of a new data control system suitable for use with large skin-milling machines has been built for the Air Material Command. It was developed in collaboration with the US Cincinnati Milling Machine Co.

Tracks target, ensures aim

First details of a new radar and fire control system which automatically tracks a target even when it is invisible to a pilot and ensures that weapons are correctly aimed were released on the 27th of June. Developed by Ferranti Ltd for Britain's new supersonic all-weather fighter—the English Electric P1B—it is called AIRPASS (Airborne Interception Radar and Pilots' Attack Sight System) and is claimed to be one of the most advanced and versatile airborne radar systems in the world.

Taking over from ground radar, which sets the pilot in the general direction of an approaching target, the AIRPASS beam scans a wide sector of sky, horizontally and vertically, on either side of the flight path and extending many miles ahead. When the target is located the radar locks on and a computer automatically works out the pilot's best approach course. Information is fed to the sighting system so that the pilot can manoeuvre into a suitable position from which to attack. Modern speeds and operating conditions and longer-range weapons have considerably reduced the effectiveness of visual contact aided by ground radar alone. With this new system, say Ferranti, the whole operation may be completed without the pilot having seen the target. But if it should come into view he can take advantage of the visual sighting methods which are included. An automatic warning device is incorporated to tell the pilot when to break off the attack if he should approach near enough to be in danger of colliding with the target.

The radar unit of AIRPASS is housed in a single container or 'bullet' and is small enough to be installed even in lightweight fighters. In the P1B it forms a centre-body in the engine air-intake. Several demonstrations have been given to overseas air forces, the latest being at Bonn on the 10th of June to West German officers.

METALS

Fully automatic rolling mill soon?

The first control system in the UK to include automatic programming of screw-down, manipulation, and rolling speed is expected to be completed in August by English Electric at Colvilles' Dalzell steel works, near Glasgow. Most of the equipment was made at the headquarters of English Electric's Control and Electronics Division at Kidsgrove, which specializes in the high-power automatic regulating equipment required for steel mills, colliery winders, turbo-alternators, etc. Feedback control is employed in some of the systems designed there, and much use is made of magnetic amplifiers, constructed in the works. In the last few weeks new bays have been added which when fully equipped will nearly double previous manufacturing capacity. There are of course many aspects of industrial control which are not at present undertaken at Kidsgrove, but the manager of the works, Mr J. O. Trundle, foresees a broadening of activity and a continuing expansion in the years ahead. The bulk of the works is devoted to computers and control equipment: DEUCE digital computer is made there, and recent ancillary developments include the provision of a more rapid alternative paper-tape input—in addition to punched cards—and auxiliary storage on magnetic tape, which makes DEUCE suitable for handling data-processing work. The company's engineers are also actively engaged in the development of analogue computers, an example of which is LACE, originally designed for guided weapon research.

After wiring and assembly at English Electric's Control and Electronics Division these impregnated resistor blocks are incorporated in high-accuracy potentiometers for use in conjunction with steel rolling-mill automatic programming equipment

Control sets its own set point

A cascade control system designed to run oil-and-gas-fired open-hearth furnaces at the same heat input irrespective of variations in either fuel supply has been installed at Colvilles' steel works in Ravenscraig, Scotland. Among other eventualities which the system copes with automatically are excessive furnace roof temperatures and the periodic need for reversal of firing. Basic idea of this Honeywell Controls installation is the co-ordination of five variables by a master controller which alters the set points of secondary controllers.

Final control action is taken by these secondary controllers for oil, gas, steam and combustion air flow. The settings on these are themselves determined by the master controller, which continuously measures total input and compensates for lack of either fuel by raising the set point on the controller for the other. This is carried out by instruments on the secondary controllers which act in proportion to a pneumatic signal received from the master. The total fuel supply is in turn subject to the overriding action of two roof temperature controllers, acting on signals from radiation pyrometers focused on each end of the roof. When either of these temperatures approaches danger point one of the roof controllers takes over and holds the furnace temperature at peak operating value. During the final stages of the melt, the two roof temperature controllers are adjusted in tandem to give closer regulation of heat input. For automatic reversal, which occurs either on a time signal or high-temperature signals from the pyrometers, oil, gas, and steam valves are closed in sequence; the dampers change over and the fuel and air are then readmitted.

More automation in aluminium

As part of the £10M expansion scheme at Northern Aluminium's Rogerstone works a new 4-high breaking down and plate finishing mill has been ordered. 'Following the trend towards increased use of automation in modern rolling mills,' said a spokesman from Davy and United Engineering Co, who will make the plant, 'a number of instruments will be fitted to control certain functions of its operation automatically.' However, he could not reveal at present whether controls include anything beyond strip thickness and the use of radioactive isotopes. The order is worth over £1M.

FOOD

Automation—cryogenic?

With the recent completion of a new instrumentation project J. Lyons & Co's ice-cream factory at Greenford becomes one of the most modern in the world; the

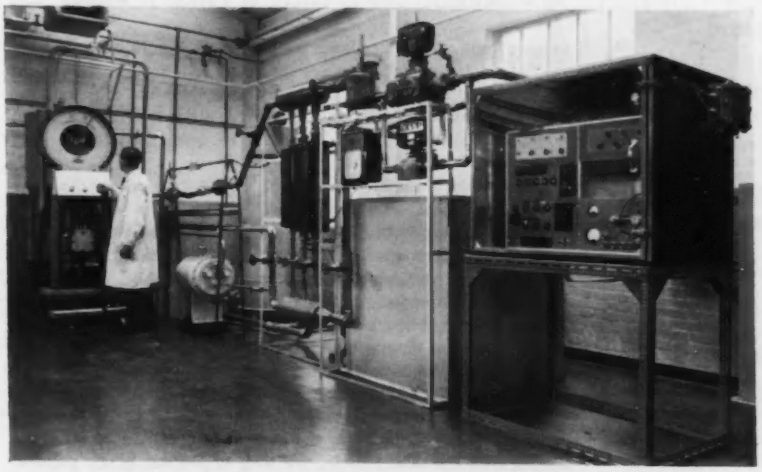
result of a joint design effort with Elliott Brothers (London) Ltd, the high degree of automation enables engineers in the control room to see at a glance the state of ingredients in storage tanks and vats throughout the works. Weights and temperatures of sixteen raw materials and mixes are monitored in a continuous cycle and shown in figures on a 22 ft central control panel under mimic diagrams illustrating liquid levels. Preset alarms with minimum and maximum settings have been incorporated and visual alarm warnings appear on the appropriate diagram. All telemetering is electric; standard Elliott load cells under the vats feed information on weights which range from 0–800 lb in 1 lb increments up to 15 tons in steps of 50 lb into the panel display units via servo-operated Elliott-Giannini recorders and translator units. Temperatures are measured by precision-wound platinum resistance thermometers in steps of one degree from − 32° to 140°F. Automatic logging of all weight and temperature data is planned, and the panel has been designed with a view to future incorporation of a desk-mounted automatic printing unit nearby.

INSTRUMENTATION

UK sets pace in flow testing

A fuel flow testing establishment which is probably the most comprehensive in Europe was opened on 6th June by Mr Aubrey Jones, Minister of Supply. Built as an extension to their works on the Treforest Trading Estate near Cardiff by Firth Cleveland Instruments Ltd, it has particular application to the oil and aircraft industries but its facilities are available to all firms handling fluids, and the company say they will welcome inquiries about it. Full provision is made for calibrating and testing flowmeters, water separators, filters, valves and other apparatus.

After the opening ceremony, Mr C. W. Hayward, Chairman of the Firth Cleveland Group, disclosed that the instrument company were now ready to undertake certain industrial process control and that they were beginning to manufacture under licence American equipment designed by the Gilbert and Barker Manufacturing Co; it will be modified as necessary for use in Britain.



The Flowmeter Test Rig No 3 and test chamber in the new Firth Cleveland establishment can be used for flow rates from 10 to 3000 i.g.p.h. in a temperature range of − 40 to 55° C

Atomonitor aids checking

The checking of assemblies to make sure hidden parts are included is now being carried out automatically at Picatinny Arsenal in America by using radioactive silver in conjunction with a machine called the Atomonitor. The absence of a ½ in. dia. collar makes artillery shell fuse heads dangerous to use and they had to be inspected in the past by the laborious and rather chancy method of shaking them and listening for a certain click which indicated that the firing pin was seated properly. After studying various ways of getting over the problem, the Army Ordnance Corps decided that the use of radioactive silver was safe and feasible and handed a specification to the Instrument Division of the Nuclear Corporation of America, who worked out the details of a machine and built it.

The parts which the £7000 Atomonitor looks for are plated with 1/100th of a microcurie of radioactive silver, and assemblies to be inspected pass through the machine on its conveyor at a rate of up to 3000 an hour. A geiger counter checks each unit and any which give no response are automatically rejected. Counters indicate inspection and rejection totals and an alarm is actuated if the rejection rate exceeds a predetermined maximum. It is claimed that only one in 10 million faulty units is missed with a probability of one in 100 000 for mistaken rejection. Other applications planned by the Corporation include the inspection of instruments, electronic and electrical apparatus and motor components.

EXPANSION AT EVERSHED & VIGNOLES

Opening Evershed & Vignoles' new head offices at Chiswick, Sir Christopher Hinton (centre), CEGB Chairman, said their pleasant conditions reflected the emphasis which the company rightly placed on human problems in the process control industry. He is seen arriving with his wife and D. D. Walker, the managing director

. . . *IN BRIEF*

'Operator control' Responsibility for checking quality should be transferred from inspectors 'after the event' to production operators themselves, urges a report issued by The Institution of Production Engineers on 3rd July. Prepared by a committee under R. K. Grunan, of Rolls-Royce, it is entitled 'Quality—its creation and control' and recommends replacing traditional works inspection departments by a quality department.

Counting loaves The day's production of bread and rolls at the new bakery of United Caterers Ltd is now checked by using Electronic Machine Co counters fitted to conveyors between the first provers and the moulding machine.

Automatic call routing Highlight of Automatic Telephone and Electric's display at the Poznan Trade Fair was a working model of the Magnetic Drum Director which is installed at the Lee Green automatic exchange in south east London; it is capable of routing more than a hundred calls to different destinations simultaneously.

Automatic film reader for rockets It has been disclosed that a film reader developed by Southern Instruments Ltd (Computer Division) for the MOS rocket research station at Aberporth can automatically analyse 35 mm film records of information on pressure, temperature, speed etc received by radio link. It was designed with the help of R. H. Tizard, at that time head of the Control Mechanisms and Electronics Department at the NPL.

SELECTED BOOKS

Non-linear digest

Analysis and Control of Non-linear Systems **by Y. H. Ku.** *Ronald Press. New York. 1958. 366 pp. $10*

The extraordinary volume of literature now appearing on the topic of non-linear systems is exemplified by the 735 references listed in the bibliography of this book, no fewer than 118 of these having been published in 1956, the last whole year included. Even this is far from complete, no papers from the *Transactions of the Society of Instrument Technology*, for example, being mentioned, and only a very few Russian works. It is clear, then, how great is the need for textbooks to digest this mass of information, and a number of these are now being published. All real systems are non-linear to some extent, but an indication of their behaviour in the presence of small disturbances can often be obtained by means of a linear approximation. Such an analysis will often meet the needs of the control system designer, who is concerned primarily with the onset of instability and its elimination. If it does not he usually has recourse to simulators and analogue solutions. The radio engineer, on the other hand, often requires information about the regions of oscillation which he wishes to maintain continuously, and techniques of linearization are apt to be less useful to him. The object of analysis is thus to give him some insight into the modes of behaviour of non-linear systems and the reasons lying behind them.

Professor Ku's book is intended to cover both fields. He gives a solid introduction to classical non-linear mathematics and describes in detail his own extension of the phase-plane method of solution, which permits a similar solution of systems governed by third- and fourth-order equations. His exposition of the method of harmonic linearization is not equally satisfactory, particularly since this is the most powerful analytical tool currently available to the control system designer, and the method of piece-wise linearization is not even mentioned. The short chapter devoted to classical linear oscillation theory might well have been omitted, since its content is readily available elsewhere. The book is well produced and has an adequate index.

R. H. MACMILLAN

Desert island discourse

Basic Automatic Control Theory **by Gordon J. Murphy.** *Van Nostrand. 1957. 568 pp. £3 7s 6d.*

Here is another 'Bumper Book for the Boys'; with its five-hundred-odd pages it handsomely passes the bump test. Since it starts right at the beginning of control theory every mechanically minded schoolboy could get started—in theory—since it is all there, he could also finish, although he would be quite used to his long trousers by the time he did.

One wonders whether to attempt such encyclopaedic coverage is wise. It almost invariably means the identity of the author is lost amid the tangle of his borrowings from others. From internal evidence one feels that Dr Murphy is a teacher by persuasion, not necessity, who has a flair for mathematics and who indeed likes to have a sound mathematical background to his lectures. Now this surely is a very good thing—a book of modest dimensions outlining control theory from this point of view would have much to be said for it. It would probably have the supreme merit of authenticity, which the present volume lacks in much of its bulk. The method adopted by the author is to introduce by a rather naïve discussion of hardware the context of control theory before dealing with the theory itself; and then to provide in one volume a number of ancillary services such as chapters on the Laplace transform, flow diagrams, and analogue computing, with appendixes on the theory of equations and function theory. These decorative limbs are stuck onto a substantial body of frequency response technique (*the same old stuff*), Laplace operational calculus (*better*) and time response (*quite good*). The last of these titles is allowed to cover a number of things that seem to have interested

the author; the root locus method figures substantially, and some interesting operational theorems are considered. It is here that we recognize the real Dr Murphy coming through.

One cannot help having a certain awed respect for the author who at first blush dashes into such length with such apparent willingness. The quality, as has been hinted, is variable, but there is no reason to believe that were you stranded on a desert island with only Dr Murphy's manual you could not become a very passable control engineer—if that happened to be your bent. Failing that, you could certainly lecture on the subject most plausibly.

J. H. WESTCOTT

Russian semiconductor achievement

Semiconductor Thermoelements and Thermoelectric Cooling *by* **A. F. Ioffe.** *Infosearch. 1958. 110 pp. £2 2s.*

This book will be of interest to all concerned with recent progress in the use of semiconductors for less well-known applications. Obviously intended to focus attention on recent achievements by Russian scientists, the English translation also impresses the reader with the author's keen insight and appreciation of the importance of the subject for modern industry. The history of thermoelectric phenomena, first observed in metals, is well covered in the Introduction, followed by a chapter on the principles of the semiconductor thermoelectric generator. Formulae are given with conditions for achieving the maximum operating efficiencies, which are much higher than with the best metal couples. Some low-power generators, energized from the waste heat of oil lamps, are illustrated, and more powerful types, delivering 200–500 W, are mentioned.

The second half of the book deals with thermoelectric cooling, with useful formulae, experimental investigations and an account of the present state of development, including applications. Commercial refrigerators are described and their advantages over standard types discussed. The description and illustrations of thermoelectric batteries, which are fabricated from selected semiconductor alloys produced by methods of powder metallurgy, are of special interest, since they would appear to open up a wide range of new applications for these materials.

Control systems engineers will be interested by a unique temperature control technique, made possible by the minute battery elements; it is likely to be extensively used in special applications where automatic temperature control of small areas is required.

In the absence of similar British or American publications, which this book may stimulate, it is difficult to judge, from the data given, the merits of the claims made concerning commercial production. But it is certain, as the author admits, that there are many physical, chemical and engineering problems to be solved before full use can be made of semiconductors.

T. H. KINMAN

Control Engineers Handbook *edited by* **J. G. Truxal.** *McGraw-Hill. 1958. 1120 pp. £7 3s 6d.*

American technical publishers, and particularly McGraw-Hill, have gained a deserved reputation for high-quality reference books. The 'Control Engineers Handbook' is no exception, and its publication both fills a gap in engineering literature and provides a timely reminder of the present crystallizing of control engineering as a separate technology. Written by 36 contributors, the book discusses, *inter alia*, feedback theory, design techniques, computers, magnetic amplifiers, hydraulic, pneumatic and mechanical components, transducers and process control. The emphasis is on components rather than system design, and this is useful in the light of the many books now available on control systems. An admirable preface by Truxal discusses the unifying role that control engineering can play in the world of technology.

No one is ever quite satisfied with a reference book's content, but this one can be warmly recommended. With the rapid development of the subject it will clearly need frequent revision.

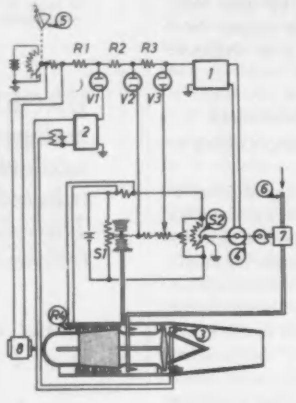
INVENTIONS OF INTEREST

Notes on recent patents in the control field

Speed control for a gas turbine inhibits dangerous operating conditions

A d.c. speed error signal is applied in this gas turbine speed-control system to the fuel valve positioning motor if (i) the exhaust temperature tends to exceed a critical maximum value, or (ii) the fuel supply reaches the maximum critical value for compressor 'stalling' or the minimum value for combustion chamber 'blow-out'. The critical maximum is varied in accordance with the compressor discharge pressure and the inlet temperature, which both influence the incidence of the stall conditions. The error between the compressor speed measured by a tachogenerator and that set by the hand throttle is passed to the amplifier through resistances R1, R2 and R3. The amplifier output is fed to the servomotor which positions the valve for the required fuel supply.

If the exhaust temperature sensed by the thermocouples exceeds that set on the potentiometer, the output of the amplifier is such that it will cause diode 1 to conduct if a positive speed error exists on the anode. The consequent voltage drop across R1 will reduce the input to the amplifier and hence the fuel supply to the engine.



1. Fuel supply amplifier
2. Exhaust temperature amplifier
3. Exhaust temperature thermocouples
4. Servomotor
5. Hand throttle
6. Fuel pipe
7. Fuel valve
8. Tachogenerator

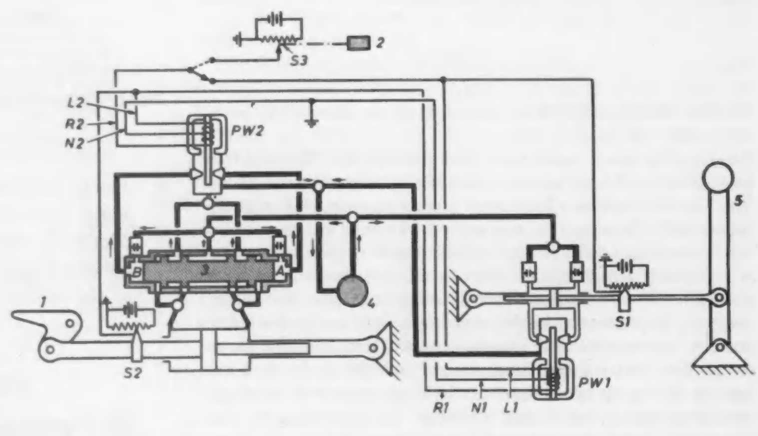
The cathode voltage of diode 2 is determined by the relative position of sliders S1 and S2. S1 is positioned between the lower bellows which is responsive to compressor discharge pressure and the upper evacuated bellows which corrects for ambient pressure. S2 is positioned by the fuel supply setting. The two sliders are effectively connected in a bridge circuit energized from a battery. Thus at a maximum fuel supply, modified by the compressor discharge pressure, the cathode of diode 2 will become negative and start to conduct. In turn this reduces the amplifier input and the fuel supply. A temperature-sensitive resistance R4 in the compressor inlet is connected in the bridge circuit to provide for variation in the maximum fuel supply with changes in inlet temperature. The anode of diode 3 is mainly affected by the position of S3, so that at a predetermined minimum fuel supply the anode will be positive relative to a negative speed error voltage on the cathode. The positive anode will allow the valve to conduct, causing an increase in the fuel supply.

789 304. **Automatic control systems for gas turbines. General Electric Co. 20th November 1957.**

Position feedback and 'feel' on aircraft control system

A fully powered aircraft control system comprises a pilot's control element coupled to a reversible servomotor and a position transmitter, a flight controller (e.g. a control surface) coupled to a second servomotor and position transmitter, and means for energizing the two servomotors. The control signal may be manual or from an automatic pilot. If the pilot's control lever is moved to the right the current from slider S1 unbalances the polarized windings PW1 and restricts the flow through the right-orifice by moving the flap to that side. The consequent build up in pressure on the right-hand side of the piston will produce a centering force (known as 'feel') on the pilot's control lever. At the same time the current from S1 unbalances the polarized windings PW2 through R2 and the flap moves to the right, restricting the flow through the orifice on that side. This restriction builds up the pressure in chamber A and the valve moves to the left, admitting oil to the left-hand end of the hydraulic jack and exhausting it from the other. The piston moves to the right and deflects the control surface. In addition the signal from S2 is increased which will decrease the current unbalance in the lines L2 and R2. The surface continues to deflect until the reaction on the surface equals the force applied by the hydraulic jack, i.e. proportional to the current difference between lines L2 and R2. This is also the current difference between ines L1 and R1, so that the centering force applied to the pilot's control lever is proportional to the load on the control surface. If automatic control is required, then a two-way switch can connect line R2 to a slider S3 controlled from an autopilot. Specification 712 329 is referred to.

791 623. **Fluid-pressure servomotor-control systems. British Messier Ltd. 8th January 1958.**



1. Control surface 2. Autopilot 3. Valve 4. Hydraulic pump 5. Pilot's control lever

These abstracts are made from British Patent Specifications with the permission of the Controller of Her Majesty's Stationery Office. Complete specifications can be obtained from the Patent Office (Sales Branch), 25 Southampton Street, London, WC2. Price 3s 6d a copy (including postage, inland and abroad)

CONTROL BUYERS' GUIDE

to manufacturers and suppliers

JULY 1958

Additional copies of this Buyers' Guide, separately bound, can be purchased from CONTROL, 3 *Percy St, London,* W1, *price* 3/6 *post free*

ADDRESS SECTION

ACCLES & POLLOCK LTD
Oldbury, Birmingham tel: Broadwell 1500

ACCURATE RECORDING INSTRUMENT CO
Aric Works, Garth Rd, Morden, Surrey tel: Derwent 2211

ACOUSTICAL MFG CO LTD
Huntingdon, Hunts tel: 361

ADAMSON & CO LTD, DANIEL
Dukinfield, Ches tel: Ashton 2822

ADEQUATE WEIGHERS LTD
Bridge Works, Sutton, Surrey tel: Vigilant 6666

ADDISON ELECTRIC CO LTD
Bosworth Rd, London, W10 tel: Ladbroke 4280

ADS RELAYS LTD
12 Store St, London, WC1 tel: Museum 2453

ADVANCE COMPONENTS LTD
Roebuck Rd, Hainault, Ilford, Essex tel: Hainault 4444

AERASPRAY ASSOCIATED LTD
179/213 Thimble Mill Lane, Birmingham 7 tel: East 1617

AEROGRAPH CO LTD, THE
47 Holborn Viaduct, London EC1 tel: City 4361

AERONAUTICAL & GENERAL INSTRUMENTS LTD
Purley Way, Croydon, Surrey tel: Thornton Heath 3211

AEROSTYLE LTD
Sunbeam Rd, London, NW10 tel: Elgar 3464

AEROX LTD
Lister Place, Hillington Industrial Estate, Glasgow, SW2 tel: Halfway 4615

AEW LTD
Imperial Works, High St, Edgware, Middx tel: Edgware 5278

AIR AUTOMATION
26 Sharrocks St, Wolverhampton tel: 24579

AIR CONTROL INSTALLATIONS LTD
Ruislip, Middx tel: 4066

AIR PUMPS LTD
Bushey Rd, London, SW20 tel: Wimbledon 9441

AIR TRAINERS LINK LTD
Bicester Rd, Aylesbury, Bucks tel: 4611

AIRCRAFT-MARINE PRODUCTS (GREAT BRITAIN) LTD.
60 Kingly St, London, W1 tel: Regent 2517

AIREDALE ELECTRICAL & MFG CO LTD
Harrogate Rd, Apperley Bridge, Bradford tel: Switch Idle 686

AIRFLOW DEVELOPMENTS LTD
Lancaster Rd, High Wycombe, Bucks tel: High Wycombe 1326

AIRMEC LTD
High Wycombe, Bucks tel: 2060

AIRTECH LTD
Haddenham, Bucks tel: 422

ALL POWER TRANSFORMERS LTD
Chertsey Rd, Byfleet, Surrey tel: 4411

ALDIS BROS LTD
Hall Green, Birmingham, 28 tel: Springfield 3343

ALLEN WEST & CO LTD
Lewes Rd, Brighton, 7 tel: Brighton 23291

ALEXANDER CONTROLS LTD
Reddicap Hill, Sutton Coldfield, Warws tel: 5227

ALLEY & MACLELLAN (POLMADIE) LTD
Polmadie, Glasgow, S2 tel: Pollok 2966/9

ALLIED ELECTRONICS LTD
28 Upper Richmond Rd, Putney, London, SW15 tel: Vandyke 1856

ALLIS-CHALMERS MFG CO
Commercial Rd, Totton, Hants tel: 2491

ALPHA ACCESSORIES LTD
Cae Mawr Factory, Treorchy, Rhondda, Glam, South Wales tel: Pentre 3273/5

ALTO INSTRUMENTS (GREAT BRITAIN) LTD
Maxwell Ho, Arundel St, Strand, London, WC2 tel: Temple Bar 3721

ALTON BATTERY CO LTD, THE
Alton Mills, Alton, Hants tel: Alton 2267/8

AMPLIVOX LTD
52 Margaret St, London, W1 tel: Langham 7918

AMOS (ELECTRONICS) LTD
45/9 High St, Bletchley, Bucks tel: Bletchley 2621

ANALYTICAL MEASUREMENTS LTD
Dome Bldgs, The Quadrant, Richmond, Surrey tel: Richmond 3392

ANDEC LTD
Bennet Rd, Reading tel: Reading 82401

ANDERS ELECTRONICS LTD
91 Hampstead Rd, London, NW1 tel: Euston 1639

ANDREWS (ELECTRO-MECHANICAL) LTD, J. B
Wrafton Works, Hartfield Crescent, London, SW19 tel: Cherrywood 1151

ANGUS & CO LTD, GEORGE
Angus Ho, Westgate Rd, Newcastle-on-Tyne, 1 tel: 22656

ANTEX LTD
3 Tower Hill, London, EC3 tel: Royal 4439

APV CO LTD, THE
Manor Royal, Crawley, Sussex tel: 1360

APPARATUS & INSTRUMENT CO LTD
15 Sheen Lane, Mortlake, London, SW14 tel: Prospect 2885

APPLEBY & IRELAND LTD
Kempshott Park, Basingstoke, Hants tel: Dummer 216

APPLIED RADIATION LTD
Harrogate Rd, Apperley Bridge, Bradford, Yorks tel: Idle 686

ARCOLECTRIC (SWITCHES) LTD
Central Avenue, West Molesey, Surrey tel: Molesey 4336

ARDENTE ACOUSTIC LABORATORIES LTD
8/12 Minerva Rd, London, NW10 tel: Elgar 3923

ARDLEIGH ENGINEERING LTD
Langham, Colchester, Essex tel: Colchester 3209

ARENS CONTROLS LTD
Tunstall Rd, East Croydon, Surrey tel: Addiscombe 3051

ARMSTRONG-WHITWORTH AIRCRAFT LTD, SIR W. G
Baginton, Coventry tel: Tollbar 2261

ARNOLD-GOODWIN LTD
4a Alt Grove, St George's Rd, London, SW19 tel: Wimbledon 6275

ARON ELECTRICITY METER LTD
72/82 Salusbury Rd, London, NW6 tel: Maida Vale 0182

ARROW ELECTRIC SWITCHES LTD
Hanger Lane, London, W5 tel: Perivale 4451

ASEA ELECTRIC LTD
Fulbourne Rd, London, E17 tel: Larkswood 2350

ASHWORTH & CO LTD, THOMAS
Vulcan Works, Rosegrove, Burnley, Lancs tel: Burnley 5259

ASHWORTH & PARKER LTD
Riverside Works, Bury, Lancs tel: 620

ASSOCIATED AUTOMATION LTD
70 Dudden Hill Lane, London, NW10 tel: Willesden 5141

ASSOCIATED ELECTRONIC ENGINEERS LTD
Dalston Gardens, Stanmore, Middx tel: Wordsworth 4474

AT & E (WIGAN) LTD
Pioneer Works, Wigan, Lancs tel: Wigan 44272

ATKINS, ROBERTSON & WHITEFORD LTD
Industrial Estate, Thornliebank, Glasgow tel: Giffnock 1031/2

ATKINSON ELECTRICAL & ENGINEERING CO. LTD, THE
Commercial Rd, Penryn, Cornwall tel: Penryn 3188/9

ATLAS CARBON & BATTERY CO LTD
56 Southwark Bridge Rd, London, SE1 tel: Waterloo 7005

ATLAS COPCO (GREAT BRITAIN) LTD
Beresford Avenue, Wembley, Middx tel: 4426

AUSTINLITE LTD
28 St. James's Sq, London, SW1 tel: Trafalgar 1954

AUTO-KLEEN STRAINERS LTD
Lascar Works, Hounslow, Middx tel: 6441

AUTOMATIC TELEPHONES & ELECTRIC CO LTD
St. Vincent St, Liverpool, 3 tel: Royal 8884

AUTOMOTIVE PRODUCTS CO LTD (LOCKHEED INDUSTRIAL HYDRAULICS DIVISION)
Tachbrook Rd, Leamington Spa, Warws tel: 2700

AUTOPHONE LTD
73 Great Peter St, London, SW1 tel: Abbey 6242

AVA LTD
Thames Works, 8 Lower Teddington Rd, Hampton Wick, Kingston-on-Thames tel: Kingston 1981

AVELEY ELECTRIC LTD
15 Ayrton Rd, Aveley Industrial Estate, South Ockendon, Essex tel: South Ockendon 2021

AVERY LTD, W & T
Soho Foundry, Birmingham, 40 tel: Smethwick 1112/7

AVERY-HARDOLL LTD
Oakcroft Rd, Chessington, Surrey tel: Elmbridge 5221

AVICA EQUIPMENT LTD
Mark Rd, Hemel Hempstead, Herts tel: Boxmoor 4711

AVIMO LTD
Taunton, Somerset tel: Taunton 3634

AVO LTD
92/6 Vauxhall Bridge Rd, London, SW1 tel: Victoria 3404

BABCOCK & WILCOX LTD
209 Euston Rd, London, NW1 tel: Euston 4321

BAILEY & CO LTD, SIR W. H
Albion Works, Patricroft, Manchester tel: Eccles 3487

BAILEY & MACKEY LTD
Baltimore Rd, Birmingham, 22b tel: Great Barr 1732

BAILEY METERS & CONTROLS LTD
Purley Way, Croydon, Surrey tel: 4191

BAIRD & TATLOCK (LONDON) LTD
Freshwater Rd, Chadwell Heath, Essex tel: Seven Kings 6081

BAIRD TELEVISION (HARTLEY BAIRD LTD)
37/9 Thurloe St, London, SW7 tel: Knightsbridge 2511

BAKER OF HOLBORN LTD, C
244 High Holborn, London, WC1 tel: Holborn 1427

BALDWIN INSTRUMENT CO LTD
Brooklands Works, Dartford, Kent tel: 2948

BANNER ELECTRIC CO LTD, THE
Burford Ho, Hoddesdon, Herts tel: Hoddesdon 2659

BARNET ENSIGN LTD
Fulbourne Rd, London, E17 tel: Larkswood 1081

BARNET INSTRUMENTS LTD
Bath Place, Barnet, Herts tel: 0066

BARR & STROUD LTD
Anniesland, Glasgow, W3 tel: Scotstoun 4241

BATY & CO LTD, J. E
39 Victoria St, London, SW1 tel: Abbey 7382

BAUSCH & LOMB OPTICAL CO LTD
Africa Ho, Kingsway, London, WC2 tel: Holborn 6604

BAYLEY, CLANAHAN & CO LTD
44 Brazennose St, Manchester, 2 tel: Blackfriars 6411

BEAKBANE (FORTOX) LTD, HENRY
The Tannery, Stourport-on-Severn, Worcs tel: 2017

BECK LTD, R. & J
69 Mortimer St, London, W1 tel: Museum 9696

BECKETT & PARKER LTD
157–159 Summer Lane, Birmingham, 19 tel: Aston Cross 3388

BELCLERE CO, THE
117 High St, Oxford tel : Oxford 48362

BELL PRECISION ENGINEERING CO LTD
Victoria Works, High St, Crawley, Sussex tel: Crawley 25757

BELLING & LEE LTD
Great Cambridge Rd, Enfield, Middx tel: 3322

BELLINGHAM & STANLEY LTD
71 Hornsey Rise, London, N19 tel: Archway 2270

BELMOS CO LTD, THE
Bellshill, Lanarkshire tel: Bellshill 2284

BEN PATENTS LTD
High Wycombe, Bucks tel: High Wycombe 1630

BERRY & CO LTD, HENRY
Croydon Works, Leeds, 10 tel: 75481

BESSON & ROBINSON LTD
East Industrial Estate, Harlow, Essex tel: Harlow 25231/4

BIF ENGINEERING CO (1940) LTD
212 Aston Rd, Birmingham, 6 tel: Aston Cross 1588/9

BIRFIELD INDUSTRIES LTD
Stratford Ho, Stratford Place, London, W1 tel: Grosvenor 7090

BIRFLO CONTROLS LTD
Bradford St, Birmingham, 5 tel: Midland 6621

BISHOP SOUND & ELECTRICAL CO LTD
48 Monmouth St, London, WC2 tel: Temple Bar 7484/5

BIVAC AIR CO LTD
Beehive Works, Marsland St, Portwood, Stockport, Ches tel: 3468

B & K LABORATORIES LTD
57 Union St, London, SE1 tel: Hop 4567

BLACK AUTOMATIC CONTROLS LTD
Leafield, Corsham, Wilts tel: Hawthorn 136

BLAKEBOROUGH & SONS LTD, J
Brighouse, Yorks tel: 511

BLICKVAC ENGINEERING LTD
Bedesway, Bede Trading Estate, Jarrow, Co Durham tel: Jarrow 89–7155

BLOCTUBE CONTROLS LTD
Bicester Rd, Aylesbury, Bucks tel: 3494

BLUNDELL & CROMPTON LTD
West India Dock Rd, London, E14 tel: East 3838

BMB (SALES) LTD
Boscobel, High St, Crawley, Sussex tel: 1030

BOBY & CO LTD, WILLIAM
23 High St, Rickmansworth, Herts tel: 4251

BONOCHORD LTD
48 Welbeck St, London, W1 tel: Welbeck 8245

BOOSEY & HAWKES LTD (Electronics Division)
Sonorous Works, Deansbrook Rd, Edgware, Middx tel: Edgware 5581

BOOTH & CO LTD, JAMES
Argyle Street Works, Nechells, Birmingham, 7 tel: East 1521

BOULTON PAUL AIRCRAFT LTD
Wolverhampton, Staffs tel: Fordhouses 3191
BPL (INSTRUMENTS) LTD
Houseboat Works, Radlett, Herts tel: 5674
BRADLEY LTD, G & E
Electral Ho, Neasden Lane, London, NW10 tel: Gladstone 0012
BRADMATIC LTD
10 Station Rd, Aston, Birmingham, 6 tel: East 2881
BRAY LTD, E. N
Control Gear Works, Britannia Rd, Waltham Cross, Herts tel: 2212
BRENTFORD TRANSFORMERS LTD
Manor Royal, Crawley, Sussex tel: Crawley 25121
BRISTOL PNEUMATIC TOOLS LTD
Causeway Works, Fishponds, Bristol tel: Bristol 53264
BRISTOL'S INSTRUMENT CO LTD
Century Works, London, SE13 tel: Tideway 1271
BRITANNIA BATTERIES LTD
53 Victoria St, London, SW1 tel: Abbey 6168
BRITEX (SCIENTIFIC INSTRUMENTS) LTD
523-4 Bank Chambers, 329 High Holborn, London, WC1 tel: Holborn 7166
BRITISH ARCA REGULATORS LTD
34 Millbank, London, SW1 tel: Victoria 4051
BRITISH BROWN-BOVERI LTD
75 Victoria St, London, SW1 tel: Abbey 5777
BRITISH CAPEHART CORPORATION LTD
Ackman Works, Ackman Rd, London, SW6 tel: Renown 1327
BRITISH CENTRAL ELECTRICAL CO LTD
6-8 Rosebery Avenue, London, EC1 tel: Terminus 0111
BRITISH DRIVER-HARRIS CO LTD
Gaythorn Mill, Albion St, Manchester, 15 tel: Central 1911
BRITISH ELECTRIC RESISTANCE CO LTD, THE
Queensway, Enfield, Middx tel: Howard 2411
BRITISH ELECTRICAL & MFG CO LTD
7-13 Clavering Place, Newcastle-on-Tyne, 1 tel: Newcastle 22416
BRITISH ERMETO CORPORATION LTD
Beacon Works, Hargrave Rd, Maidenhead, Berks tel: 2271
BRITISH FEDERAL WELDER & MACHINE CO LTD
Castle Mill Works, Dudley, Worcs tel: 3114
BRITISH FILTERS LTD
Old Court, Cox Green, Maidenhead, Berks tel: 4144
BRITISH INSULATED CALLENDER'S CABLES LTD
21 Bloomsbury St, London, WC1 tel: Museum 1600
BRITISH KLOCKNER SWITCHGEAR LTD
Guildford St, Chertsey, Surrey tel: Chertsey 2067
BRITISH MANUFACTURED BEARINGS CO LTD
Crawley, Sussex tel: Crawley 1030
BRITISH MESSIER LTD
Cheltenham Rd, Gloucester tel: 24431
BRITISH OPTICAL LENS CO
Victoria Works, 315 Summer Lane, Birmingham, 19 tel: Aston Cross 1156
BRITISH PHYSICAL LABORATORIES
Radlett, Herts tel: 5674
BRITISH PITOMETER CO LTD, THE
105 Park St, London, W1 tel: Mayfair 0141
BRITISH POWER TRANSFORMER CO LTD, THE
Queensway, Enfield, Middx tel: Howard 2411
BRITISH ROTOTHERM CO LTD, THE
Merton Abbey, London, SW19 tel: Liberty 7661
BRITISH SAROZAL LTD
Sarozal Ho, Marylebone Passage, Margaret St, London, W1 tel: Langham 9351
BRITISH TABULATING MACHINE CO LTD, THE
17 Park Lane, London, W1 tel: Hyde Park 8155
BRITISH THERMOSTAT CO LTD
Windmill Rd, Sunbury-on-Thames, Middx tel: Sunbury 456
BRITISH THOMSON-HOUSTON CO LTD, THE
Rugby, Warws tel: Rugby 2121
BRITISH TIMKEN LTD
Cheston Rd, Aston, Birmingham, 7 tel: East 1321
BRITISH STEAM SPECIALITIES LTD
Fleet St, Leicester tel: 20885
BROADCAST & ELECTRONIC ENGINEERING CO LTD
Broadcast Ho, Tombland, Norwich
BROCKHOUSE ENGINEERING LTD
Victoria Works, Hill Top, West Bromwich, Staffs tel: Wednesbury 0243
BROOK MOTORS LTD
16-18 Palmer St, London, SW1 tel: Abbey 7626
BROOKE INDUSTRIES LTD
Kent Ho, Telegraph St, Moorgate, London, EC2 tel: Monarch 1105
BROOKHIRST SWITCHGEAR LTD
Northgate Works, Chester tel: 21121
BROOM & WADE LTD
High Wycombe, Bucks tel: High Wycombe 1630
BROTHERHOOD LTD, PETER
Peterborough tel: Peterborough 2251
BROWN (BROWNALL) LTD, DONALD
543 Oldham Rd, Failsworth, Manchester tel: Failsworth 2399
BROWN LTD, S. G
Shakespeare St, Watford, Herts tel: 7241
BRUCE PEEBLES & CO LTD
37 Inverleith Place, Edinburgh, 3 tel: Granton 85201
BRUSH ELECTRICAL ENGINEERING CO LTD
Loughborough, Leics tel: 3131
BRYANS AEROQUIPMENT LTD
15 Willow Lane, Mitcham, Surrey tel: Mitcham 1607

BTR INDUSTRIES LTD
Herga Ho, Vincent Sq, London, SW1 tel: Victoria 3848
BUDENBERG GAUGE CO LTD
Broadheath, nr Manchester tel: Altrincham 2617
BULLOWS & SONS LTD, ALFRED
Long St, Walsall, Staffs tel: Walsall 5401
BULMERS (CALCULATORS) LTD
47-51 Worship St, London, EC2 tel: Monarch 7991
BURGESS PRODUCTS CO LTD (Micro Switch Division)
Dukes Way, Team Valley, Gateshead, 11 tel: Low Fell 75322
BURNDEPT LTD
West St, Erith, Kent tel: 3080
BURNAND & SON LTD, W. E
66-106 Shoreham St, Sheffield, 1 tel: Sheffield 24148
BURNE-JONES & CO LTD
309 Borough High St, London, SE1 tel: Hop 0401
BURNETT & LEWIS LTD
Middlemore Lane West, Redhouse Industrial Estate, Aldridge, Staffs tel: 52888
BURRELL & CO LTD, A.G
Timer Works, Thomas St, Sheffield, 1 tel: 25435
BURTON GRIFFITHS & CO LTD
Kitts Green, Birmingham, 33 tel: Stechford 3071
CAMBRIDGE INSTRUMENT CO LTD
13 Grosvenor Place, London, SW1 tel: Belgravia 5066
CAMLAB (GLASS) LTD
Burleigh St, Cambridge tel: 57809
CANDY FILTER CO LTD, THE
14 Church Rd, Hanwell, London, W3 tel: Ealing 6733
CANNING & CO LTD, W
Great Hampton St, Birmingham, 18 tel: Central 8621
CARTER & CO LTD, B. & F
Albion Works, Bolton, Lancs tel: Bolton 4344
CARTER GEARS LTD
Thornbury Rd, Bradford, Yorks tel: 64378
CASS & PHILLIP LTD
Mark Rd, Adeyfield, Hemel Hempstead, Herts tel: Boxmoor 4156
CASELLA & CO LTD, C. F
Regent Ho, Fitzroy Sq, London, W1 tel: Euston 3944
CATTERMOLE & CO (HYDRAULICS) LTD
Feckenham Rd, Astwood Bank, Redditch, Worcs tel: Astwood Bank 142
CAV LTD
Acton, London, W3 tel: Shepherds Bush 3111
CAWKELL RESEARCH & ELECTRONICS LTD
6-8 Victory Arcade, The Broadway, Southall, Middx tel: Southall 3702
CEMENTATION (MUFFELITE) LTD
39 Victoria St, London, SW1 tel: Reliance 7654
CET ELECTRICAL & MECHANICAL COMPONENTS LTD
11-12 Fenchurch St, London, EC3 tel: Mansion House 2858
CHAMBERLAIN & HOOKHAM LTD
Solar Works, New Bartholomew St, Birmingham, 5 tel: Midland 0661
CHAMBERLAIN INDUSTRIES LTD
Staffa Rd, London, E10 tel: Leyton 3678
CHANCE-PILKINGTON OPTICAL WORKS (PILKINGTON BROS LTD)
Glascoed Rd, St. Asaph, Flints tel: 3281
CHATWOOD-MILNER LTD
Shrewsbury, Salop tel: Shrewsbury 4001
CHELTENHAM AUTO CONTROLS LTD
Windsor St, Cheltenham tel: Cheltenham 5805
CHLORIDE BATTERIES LTD
Exide Works, Clifton Junction, Swinton, Manchester tel: Swinton 2011
CHRISTIE & DICKINSON LTD, REGINALD
16-17 Devonshire Sq, London, EC2 tel: Bishopsgate 3747
CHRISTIE & SADLER LTD
68 Finsbury Pavement, London, EC2 tel: Monarch 3867
CIBA (ARL) LTD
Duxford, Cambs tel: Sawston 2121
CJR ELECTRICAL & ELECTRONIC DEVELOPMENTS LTD
Bickford Rd, Birmingham, 6 tel: East 0822
CLARE INSTRUMENT CO
8 South St, West Worthing, Sussex tel: Worthing 3407
CLARKE & SMITH MFG CO LTD
Melbourne Works, Melbourne Rd, Wallington, Surrey tel: Wallington 5156
CLARKSON & CO LTD, A
338 High Holborn, London, WC1 tel: Holborn 2149
CLAYTON-WRIGHT LTD, HOWARD
Wellesbourne, Warws tel: Wellesbourne 316
CLIMAX ROCK DRILL & ENGINEERING WORKS LTD
4 Broad Street Place, London, EC2 tel: London Wall 5111
CNS INSTRUMENTS LTD
61 Holmes Rd, London, NW5 tel: Gulliver 2418
COLEY THERMOMETERS LTD
2 London Rd, Brentford, Middx tel: Ealing 4010
COLNE SWITCHGEAR LTD, K. & W
Walton St, Colne, Lancs tel: Colne 1394
COLOSTAT COMBUSTION SYSTEMS LTD
Sidney Works, Sidney Rd, London, SW9 tel: Brixton 7887
COLOUR SPRAYS LTD
Albion Works, North Rd, London, N7 tel: North 6091
COLVERN LTD
Spring Gardens, Romford, Essex tel: 62222
COMBUSTION INSTRUMENTS
61 Belsize Lane, London, NW3 tel: Swiss Cottage 4462

COMOY PLASTICS & INSULATIONS
90-92 Pentonville Rd, London, N1 tel: Terminus 1089 and 5704
COMPTON ORGAN CO LTD, THE JOHN
Minerva Rd, London, NW10 tel: Elgar 6666
COMUCATE LTD
Woodfall Rd, London, N4 tel: Archway 4651
CONSOLIDATED PNEUMATIC TOOL CO LTD
323 Dawes Rd, London, SW6 tel: Fulham 7722
CONSTRUCTORS—JOHN BROWN LTD
73 South Audley St, London, W1 tel: Grosvenor 4181
CONTACTOR SWITCHGEAR LTD
Blakenhall, Wolverhampton tel: Wolverhampton 25911
CONVEYANCER FORK TRUCKS LTD
Liverpool Rd, Warrington, Lancs tel: 2244
COOKE, TROUGHTON & SIMMS LTD
Haxby Rd, York tel: 24112
COOPER & CO (BIRMINGHAM) LTD
Brynmawr, Breconshire tel: Brynmawr 312
COOPER-STEWART ENGINEERING CO LTD
Stewart Works, Works Rd, Letchworth, Herts tel: Letchworth 909
COPPER & ALLOYS LTD
Greets Green Rd, West Bromwich tel: West Bromwich 1774
CORK MANUFACTURING CO LTD
Langite Works, South Chingford, London, E4 tel: Silverthorn 2666
CORREX COMMUNICATIONS EQUIPMENT (1948) LTD
Phoenix Works, The Hyde, Hendon, London, NW9 tel: Colindale 7243
COSSOR INSTRUMENTS LTD
Cossor Ho, Highbury Grove, London, N5 tel: Canonbury 1234
COUNTING INSTRUMENTS LTD
5 Elstree Way, Borehamwood, Herts tel: Elstree 1382
COX-WALKERS LTD
North-Eastern Electric Works, Feethams, Darlington tel: 2387
CRAIG & DERRICOTT LTD
Royal Works, Coleshill St, Sutton Coldfield, Birmingham tel: Sutton Coldfield 2547
CRAVEN ELECTRONICS LTD
212 Manningham Lane, Bradford, 8 tel: Bradford 29654
CREED & CO LTD
Telegraph Ho, Croydon, Surrey tel: 2121
CROMPTON PARKINSON LTD
Crompton Ho, Aldwych, London, WC2 tel: Chancery 3333
CROSBY VALVE & ENGINEERING CO LTD
Crosby Works, Ealing Rd, Wembley, Middx tel: Perivale 6424
CROSFIELD LTD, J. F
2 Elthorne Rd, London, N19 tel: Archway 5466
CROYDON PRECISION INSTRUMENT CO
Hampton Rd, West Croydon, Surrey tel: Thornton Heath 4025
CRYPTON EQUIPMENT LTD
Bristol Road, Bridgwater, Somerset tel: Bridgwater 2614
CUSSONS LTD, G
Technical Works, John St, Manchester, 7 tel: Blackfriars 9503
CUTHBERT LTD, RALPH
Westgate, Huddersfield, Yorks tel: 6323
CWC EQUIPMENT LTD
Acorn Works, Kings Grove, Maidenhead, Berks tel: 2275
DALLMEYER LTD, J. H
Church End Works, Willesden, London, NW10 tel: Willesden 6521
DALLOW LAMBERT & CO LTD
Thurmaston, Leicester tel: Syston 3333
DANFOSS MFG CO
13 Queensway, London, W2 tel: Bayswater 1633
DARTON & CO LTD, F
Watford Fields, Watford, Herts tel: Watford 6019
DATA RECORDING INSTRUMENT CO LTD
Lion Works, Hanworth Trading Estate, Feltham, Middx tel: Molesey 4821
DAVALL & SONS LTD, S
8-12 Wadsworth Rd, Perivale, Greenford, Middx tel: Perivale 7807
DAVALL GEAR CO LTD
Gear Works, High St, Potters Bar, Middx tel: Potters Bar 2382
DAVEY, PAXMAN & CO LTD
Standard Ironworks, Colchester, Essex tel: 5151
DAVIDSON & CO LTD
Sirocco Eng Works, Belfast tel: 57251
DAVIS (RELAYS) LTD, JACK
Tudor Place, London, W1 tel: Museum 7960
DAVY & UNITED ENGINEERING CO LTD
Darnall Works, Sheffield, 9 tel: 49971
DAWE INSTRUMENTS LTD
99 Uxbridge Rd, Ealing, London, W5 tel: Ealing 6215
DAWSON McDONALD & DAWSON LTD
Compton Works, Ashbourne, Derbys tel: Ashbourne 113
DAY & CO (DERBY WORKS) LTD, J
Harrow Manorway, London, SE2 tel: Woolwich 7036
DECCA RADAR LTD
9 Albert Embankment, London, SE11 tel: Reliance 8111
DE HAVILLAND AIRCRAFT CO LTD (Vibration Dept)
Stag Lane, Edgware, Middx tel: Hatfield 2300
DE HAVILLAND PROPELLERS LTD
Hatfield, Herts tel: Hatfield 2300
DE LA RUE & CO LTD, THOMAS (Potterton Division)
20-30 Buckhold Rd, London, SW18 tel: Vandyke 7202

DEPENDABLE RELAY CO
12a Tottenham St, London, W1
tel: Langham 7391
DEV ENGINEERING CO LTD
299 Chapeltown Rd, Leeds, 7 tel: Leeds 49019
DEVICES SALES LTD
37 Hyde Way, Welwyn Garden City, Herts
tel: Welwyn 4146
DEVON INSTRUMENTS LTD
Countess Wear, Exeter, Devon tel: Topsham 3547
DEWHURST & PARTNER LTD
Inverness Works, Inverness Road, Hounslow, Middx tel: Hounslow 0083
DEWRANCE & CO LTD
Great Dover St, London, SE1 tel: Hop 3100
DEXION LTD
65 Maygrove Rd, London, NW6
tel: Maida Vale 6031
"DIAMOND H" SWITCHES LTD
Gunnersbury Avenue, Chiswick, W4
tel: Chiswick 6444
DIAMEX LTD
35 Lonsdale Rd, London, E11 tel: Wanstead 3200
DICK LTD, R & J
Greenhead Works, Glasgow tel: Bridgeton 2344
DICTOGRAPH TELEPHONES LTD
Aurelia Rd, Croydon tel: Thornton Heath 2427
DIGITAL ENGINEERING CO LTD
136 Battersea Park Rd, London, SW12
tel: Macaulay 5217
DOBBIE MCINNES LTD
191 Broomloan Rd, Glasgow, SW1
tel: Govan 2394
DONKIN CO LTD, THE BRYAN
Chesterfield, Derbyshire tel: Chesterfield 3153
DONOVAN ELECTRICAL CO LTD, THE
70–82 Granville St, Birmingham, 1
tel: Midland 5683
DONVIN INSTRUMENTS LTD
Electrin Works, Winchester St, Acton, W3
tel: Acorn 4995
DORAN INSTRUMENT CO LTD
Parklands, Stroud, Glos tel: Stroud 462
DOUGLAS ELECTRONIC INDUSTRIES LTD
Brinklow, Rugby tel: Pailton 45
DOULTON INDUSTRIAL PORCELAINS LTD
Doulton Ho, Albert Embankment, London, SE1
tel: Reliance 1241
DOWTY EQUIPMENT LTD
Arle Court, Cheltenham, Glos tel: 53471
DOWTY HYDRAULIC UNITS LTD
Ashchurch, Tewkesbury, Glos
tel: Tewkesbury 2271
DOWTY NUCLEONICS LTD
Brockhampton Park, Andoversford, Glos
tel: Cheltenham 391
DP BATTERY CO LTD, THE
Bakewell, Derbyshire tel: Bakewell 81
DRAYTON REGULATOR & INSTRUMENT CO LTD, THE
West Drayton, Middx tel: West Drayton 4012
DUBILIER CONDENSER CO (1925) LTD
Ducon Works, Victoria Rd, North Acton, London, W3 tel: Acorn 2241
DULCI CO LTD
97 Villiers Rd, London, NW2 tel: Willesden 6678
DUNFORD & ELLIOTT (SHEFFIELD) LTD (Automation Division)
Chippingham St, Sheffield, 9 tel: 42971
DUNLOP SPECIAL PRODUCTS LTD (Engineering Components Division)
Fort Dunlop, Birmingham, 24 tel: Erdington 2121
DYNATRON RADIO LTD (Nucleonic & Electronic Dept)
St Peter's Rd, Furze Platt, Maidenhead, Berks
tel: 2161
EAR LTD
The Square, Isleworth, Middx tel: Hounslow 6256
EASCO ELECTRICAL (HOLDINGS) LTD
6–8 Brighton Terrace, London, SW9
tel: Brixton 4961
EDGELEY STUDIOS LTD
Lansdown Place Lane, Cheltenham, Glos
tel: Cheltenham 52344
EDWARDS HIGH VACUUM LTD
Manor Royal, Crawley, Sussex tel: Crawley 1500
EGA ELECTRIC LTD
Holyhead Rd, Wednesbury, Staffs tel: 0911
EKCO ELECTRONICS LTD
Ekco Works, Southend-on-Sea, Essex tel: 49491
ELCONTROL LTD
Wilbury Way, Hitchin, Herts tel: 2411
ELECTRIC CONSTRUCTION CO LTD
Bushbury, Wolverhampton
tel: Wolverhampton 21455
ELECTRIC & MUSICAL INDUSTRIES LTD
Blyth Rd, Hayes, Middx tel: Southall 2468
ELECTRICAL APPARATUS CO LTD, THE
New Barnes Avenue, St Albans, Herts
tel: St Albans 54461
ELECTRICAL ENGINEERING CONSTRUCTION CO LTD
Seymour Wharf, Totnes, Devon tel: Totnes 3282
ELECTRICAL INSTRUMENT CO (HILLINGTON) LTD, THE
Boswell Sq, Industrial Estate, Hillington, Glasgow, SW2 tel: Glasgow Halfway 1166
ELECTRICAL REMOTE CONTROL CO LTD
East Industrial Estate, Harlow New Town, Essex
tel: Harlow 24032
ELECTRICAL THERMOMETER CO LTD, THE
1 Stroud Green Rd, London, W4
tel: Archway 4267
ELECTRO DYNAMIC CONSTRUCTION CO LTD
St Mary Cray, Kent tel: Orpington 27551
ELECTRO-HYDRAULICS LTD
Liverpool Rd, Warrington, Lancs
tel: Warrington 2244
ELECTRO MECHANICAL MFG CO LTD
Scarborough, Yorks tel: 2715

ELECTRO MECHANISMS LTD
220 Bedford Avenue, Slough, Bucks tel: 22228
ELECTRO METHODS LTD
Caxton Way, Stevenage, Herts tel: 780
ELECTROFLO METERS CO LTD
Abbey Rd, London, NW10 tel: Elgar 7641
ELECTRO-MAGNETIC CONTROL CO
5a Goldsmith Road, Leyton, London, E10
tel: Leytonstone 5421
ELECTROMAGNETS LTD
1 Bond St, Birmingham, 19 tel: Central 5391
ELECTRONIC COMPONENTS
Weedon Rd Industrial Estate, Northampton
tel: 2467
ELECTRONIC INSTRUMENTS LTD
51 Lower Mortlake Rd, Richmond, Surrey
tel: Richmond 5656
ELECTRONIC MACHINE CO
9 Mayday Rd, Thornton Heath, Surrey
tel: Thornton Heath 3788
ELECTRONIC SWITCHGEAR (LONDON) LTD
Works Rd, Letchworth, Herts
tel: Letchworth 2020
ELECTRONIC TUBES LTD
Kingsmead Works, High Wycombe, Bucks
tel: High Wycombe 2020
ELECTROTHERMAL ENGINEERING LTD
270 Neville Rd, London, E7
tel: Grangewood 0055
ELECTROWARES LTD
302 Waterloo Rd, London, SE1
tel: Waterloo 5271
ELLAY TUBES LTD
Cox Green Works, Maidenhead, Berks
tel: Maidenhead 3303
ELLIOTT BROTHERS (LONDON) LTD
Century Works, London, SE13
tel: Tideway 1271
ELLIOTT RADIO MFG CO LTD
87 Senhouse St, Maryport, Cumberland tel: 354
E & M CONSTRUCTION LTD
286 Waterloo Rd, London, SE1
tel: Waterloo 3062
EMB CO LTD
Moor St, West Bromwich
tel: West Bromwich 1171
EMECO ELECTRONICS CO
Maxwell Ho, Arundel St, London, WC2
tel: Temple Bar 1610
EMI ELECTRONICS LTD
Hayes, Middx tel: Southall 2468
EMO INSTRUMENTATION LTD
Western Rd, Bracknell, Berks tel: 675
ENDECOTTS (FILTERS) LTD
251 Kingston Rd, London, SW19
tel: Liberty 8121
ENGEL & GIBBS LTD
Warwick Rd, Borehamwood, Herts
tel: Elstree 2291
ENGELHARD INDUSTRIES LTD
Bath Rd, Slough, Bucks tel: Burnham 500
ENGINEERING PRODUCTS LTD
Littlers Close, Merton Abbey, London, SW19
tel: Liberty 1085
ENGLISH CLOCK SYSTEMS LTD
179–185 Great Portland St, London, W1
tel: Langham 7226
ENGLISH ELECTRIC CO LTD, THE
Marconi Ho, Strand, London, WC2
tel: Covent Garden 1234
ENGLISH ELECTRIC VALVE CO LTD, THE
Waterhouse Lane, Chelmsford, Essex tel: 3491
ENGLISH NUMBERING MACHINES LTD
25 Queensways, Ponders End, Middx
tel: Howard 2611
ENGINES AND ELECTRICS LTD
48 Princes Gate, London, SW7
tel: Kensington 4401
EPCO LTD
Star Works, Leeds, 7 tel: 32461
EPSYLON SOUND ACCESSORIES LTD
The Barons, St Margarets, Twickenham Middx
tel: Popesgrove 4451
EQUIPMENT & ENGINEERING CO LTD
2–3 Norfolk St, London, WC2 tel: Temple Bar 1088
ERD ENGINEERING CO LTD
Ispwich Rd, Slough, Bucks tel: Slough 20532
ERICSSON TELEPHONES LTD (Instrument Division)
High Church St, New Basford, Nottingham
tel: 75115
ERIE RESISTOR LTD
Carlisle Rd, The Hyde, London, NW9
tel: Colindale 8011
ERSKINE, HEAP & CO LTD
Lancashire Switchgear Works, Caroline St, Manchester, 7 tel: Deansgate 4561
ERSKINE LABORATORIES LTD
North St, Scalby, Scarborough tel: Scalby 483
ESCHER, WYSS LTD
Terminal Ho, Grosvenor Gardens, London, SW1
tel: Sloane 8101
ETHER LTD
Tyburn Rd, Birmingham, 24 tel: East 0276
EVANS ELECTRONIC DEVELOPMENTS LTD
Evonic Works, Shady Lane, Birmingham, 22a
tel: Great Barr 1764
EVANS ELECTROSELENIUM LTD
Westminster Bank Chambers, Bishops Stortford, Herts tel: Bishops Stortford 702
EVER READY COMPANY (GT. BRITAIN) LTD
Hercules Place, Holloway, London, N7
tel: Archway 3030
EVERETT, EDGCUMBE & CO LTD
Colindale Works, London, NW9
tel: Colindale 6045
EVERSHED & VIGNOLES LTD
Acton Lane Works, Chiswick, W4 tel: 3670
EXACTOR LTD
Exactor Works, Church Way, Edgware, Middx
tel: Edgware 0071

EXPANDED RUBBER CO LTD
675 Mitcham Rd, Croydon, Surrey
tel: Thornton Heath 3622
EXPRESS TRANSFORMERS & CONTROLS LTD
44–46 Beddington Lane, Croydon, Surrey
tel: Thornton Heath 2443
EXPRESS WINDING CO
44–46 Beddington Lane, Croydon, Surrey
tel: Thornton Heath 2443
FARADAY ELECTRONIC INSTRUMENTS LTD
245 Brixton Rd, London SW9 tel: Brixton 6455
FARNELL INSTRUMENTS LTD
Wetherby Industrial Estate, York Rd, Wetherby, Yorks tel: 2544
FARROW & SONS LTD
Spalding, Lincs tel: Spalding 3388
FAWCETT-FINNEY LTD
27 Berkeley St, Birmingham, 1 tel: Midland 3795
FEENY & JOHNSON LTD
134 Ealing Rd, Wembley, Middx tel: 4801
FEL-ELECTRIC LTD
41 Sidney St, Sheffield, 1 tel: Sheffield 27357
FAIREY AIR SURVEYS LTD
24 Bruton St, London, W1 tel: Mayfair 8791
FAIREY AVIATION CO LTD, THE
North Hyde Rd, Hayes, Middx tel: 3800
FALK & CO LTD, M
Emefco Ho, Bell St, Reigate, Surrey tel: 5341
FENNER & CO LTD, J. H
Hull, Yorks tel: Hull Central 13900
FERRANTI LTD
Moston, Manchester, 10 tel: Failsworth 2071
FERRARIS (CLERKENWELL) LTD, FRED
14 Northampton Sq, London, EC1
tel: Clerkenwell 2676
FIELDEN ELECTRONICS LTD
Paston Rd, Manchester, 22
tel: Wythenshawe 3251
FIELDEN (DEVON) LTD, J. S
Nestlecombe Ho, Branscombe, Seaton, Devon
tel: Branscombe 371
FILMS & EQUIPMENTS LTD
138 Wardour St, London, W1 tel: Gerrard 6711
FILTER CO LTD, The E. & H
36 Summer Row, Birmingham, 3
tel: Central 2834
FINDLAY & CO
Heathfield Terrace, Chiswick, W4
tel: Chiswick 7621
FIREYE CONTROLS CO LTD
14 Fetter Lane, London, EC4
tel: Fleet Street 6671
FIRTH CLEVELAND INSTRUMENTS LTD
Treforest Industrial Estate, Treforest, Glam
tel: 2211
FISCHER BEARINGS CO LTD
Upper Villiers St, Wolverhampton
tel: Wolverhampton 26101
FISCHER & PORTER LTD
Salterbeck Trading Estate, Workington, Cumberland tel: Harrington 333
FISHER GOVERNOR CO LTD
Airport Works, Rochester, Kent
tel: Chatham 44400
FLEMING RADIO (DEVELOPMENTS) LTD
Caxton Way, Stevenage, Herts tel: 804
FLIGHT REFUELLING LTD
Ringwood Rd, West Howe, Bournemouth, Hants
tel: Blandford 501
FONADEK (BRANSON) LTD
Knightsdowne Ho, Vivian Rd, Birmingham, 17
tel: Harborne 2267
FORTIPHONE LTD
Component Division, 247 Regent St, London, W1
tel: Langham 3773
FOSTER INSTRUMENT CO LTD
Pixmore Avenue, Letchworth, Herts tel: 985
FOSTER TRANSFORMERS LTD
South Wimbledon, London, SW19
tel: Liberty 2211
FOUNDROMETERS LTD
Torbay Works, Hunslet, Leeds, 10
tel: Leeds 22044
FOXBORO-YOXALL LTD
Redhill, Surrey tel: 5000
FRACTIONAL HP MOTORS LTD
West Heath Works, Rookery Way, London, NW9
tel: Colindale 8022
FRASER & CO LTD, ANDREW
29 Buckingham Gate, London, SW1
tel: Victoria 6736
FRASER & CHALMERS ENGINEERING WORKS
Erith, Kent tel: Erith 3011
FULLER ELECTRICAL & MFG CO LTD
Fulbourne Rd, London, E17 tel: Larkswood 2350
FULLERTON, HODGART & BARCLAY LTD
Vulcan Works, Paisley, Renfrew tel: Paisley 2163
FURZEHILL LABORATORIES LTD
57 Clarendon Rd, Watford, Herts
tel: Gadebrook 4686
GALLENKAMP & CO LTD, A
Sun St, London, EC2 tel: Bishopsgate 0651
GAMBRELL BROS & CO LTD
105–6 Lansdowne Rd, Croydon, Surrey
tel: Croydon 8282
GARDNERS RADIO LTD
Somerford, Christchurch, Hants tel: 1024
GASKELL & CHAMBERS LTD
Dalex Works, Birmingham, 4 tel: Central 8471
GB-KALEE LTD
37 Mortimer St, London, W1 tel: Museum 5432
GEIPEL LTD, WILLIAM
156–170 Bermondsey St, London, SE1
tel: Hopwood 0594
GENERAL ACOUSTICS LTD
Kelvin Way, Crawley, Sussex tel: Crawley 1676
GENERAL ELECTRIC CO LTD, THE
Magnet Ho, Kingsway, London, WC2
tel: Temple Bar 8000

GENERAL MOTORS LTD (Frigidaire Division, Stag Lane, London, NW9 tel: Colindale 6541

GENERAL RADIOLOGICAL LTD
15 Clipstone St, London, W1 tel: Museum 3121

GIESLER LTD, C. F. R
River Place, Essex Rd, London, N1
tel: Canonbury 5604

GENT & CO LTD
Faraday Works, Leicester tel: 36151

GLASS DEVELOPMENTS LTD
Sudbourne Rd, Brixton Hill, London, SW2
tel: Brixton 4041

GLENFIELD & KENNEDY LTD
Low Glencairn St, Kilmarnock, Ayrshire tel: 2884

GLOBE PNEUMATIC ENGINEERING CO LTD
Ashton Rd, Harold Hill, Romford, Essex
tel: Ingrebourne 3935

GLOSTER AIRCRAFT CO LTD (Technical Developments Division)
Gloucester tel: 67011

GNU ACCUMULATOR CO LTD
246–248 Cavendish Rd, London, SW12
tel: Balham 4291

GODFREY & PARTNERS (INDUSTRIAL) LTD, SIR GEORGE
Hampton Rd, Hanworth, Middx
tel: Feltham 3291

GOODMANS INDUSTRIES LTD
Axiom Works, Lancelot Rd, Wembley, Middx
tel: Wembley 1200

GORDON & CO LTD, JAMES
Dalston Gardens, Stanmore, Middx
tel: Wordsworth 3631

GRAMPIAN REPRODUCERS LTD
Hanworth Trading Estate, Feltham, Middx
tel: Feltham 2657

GRASEBY INSTRUMENTS LTD
Kingston By-Pass Rd, Tolworth, Surrey
tel: Elmbridge 5742

GRATON & KNIGHT LTD
Warwick Rd, Borehamwood, Herts
tel: Elstree 1785

GRAVINER MFG CO LTD
Fareham Rd, Gosport, Hants tel: 89175

GRESHAM TRANSFORMERS LTD
Twickenham Rd, Hanworth, Middx
tel: Feltham 2271

GRIFFIN & GEORGE LTD
Ealing Rd, Alperton, Wembley, Middx
tel: Perivale 3344

GRUBB, PARSONS & CO LTD, SIR HOWARD
Walker Gate, Newcastle-on-Tyne, 6 tel: 650411

GRUNDIG (GREAT BRITAIN) LTD
Kidbrooke Park Rd, London, SE3
tel: Lee Green 8541

GUEST INDUSTRIALS LTD
81 Gracechurch St, London, EC3
tel: Mansion House 5631

GUYSON INDUSTRIAL EQUIPMENT LTD
North Avenue, Otley, Yorks tel: 2456

GWB FURNACES LTD
PO Box No 4, Dibdale Works, Dudley, Worcs
tel: Dudley 4284

HACKBRIDGE & HEWITTIC ELECTRIC CO LTD
Walton-on-Thames, Surrey tel: 760

HADDON TRANSFORMERS LTD
Masons Avenue, Wealdstone, Harrow, Middx
tel: Harrow 9022

HADLEY TELEPHONE & SOUND SYSTEMS LTD
72 Cape Hill, Smethwick 40, Staffs
tel: Smethwick 2471

HALDEN & CO LTD, J
Rowsley Works, Reddish tel: Heaton Moor 2241

HALL & HALL LTD
Oldfield Works, Hampton, Middx
tel: Molesey 2180

HALL (ELEC ENGINEERS) LTD, J EDWARD
Clarence Road Works, Leeds, 10 tel: 34886

HALL TELEPHONE ACCESSORIES LTD
Duddenhill Lane, London, NW10
tel: Willesden 5141

HALLMAC TOOLS LTD
Aldersley, Wolverhampton tel: 52001

HAM, BAKER & CO LTD
Langley Green, Oldbury, Birmingham
tel: Broadwell 1446

HAMWORTHY ENGINEERING LTD
Fleets Corner, Poole, Dorset tel: 2020

HARBROOK ENGINEERING CO LTD, THE
70 Maidstone Rd, Rochester, Kent
tel: Chatham 41133

HARCOURT LTD, DAVID
917 Coventry Rd, Birmingham, 10
tel: Victoria 1051

HARE LTD, P. J
Wrington, Bristol tel: Wrington 262

HARLAND ENGINEERING CO LTD
BEP Works, Alloa, Scotland tel: 390

HARMSWORTH, TOWNLEY & CO
Jordan St, Manchester, 15 tel: Central 4281

HARRIS ENGINEERING CO LTD
York Works, Browning St, London, SE17
tel: Rodney 3835

HART ACCUMULATOR CO LTD
Dagenham Dock, Essex tel: Rainham 34

HARTLEY ELECTROMOTIVES LTD
37 and 39 Thurloe St, London, SW7
tel: Knightsbridge 5211

HARTLEY CO LTD, H. A
152 Hammersmith Rd, London, W6
tel: Riverside 7387

HARVEY ELECTRONICS LTD
Farnborough Rd, Farnborough, Hants
tel: Farnborough 1120

HARWIN (ENGINEERS) LTD
101–105 Nibthwaite Rd, Harrow, Middx
tel: Harrow 0381

HATFIELD INSTRUMENTS LTD
Crawley Rd, Horsham, Sussex tel: 3232

HAWKER SIDDELEY NUCLEAR POWER CO LTD
18 St. James's Sq, London, SW1
tel: Whitehall 2064

HAYNES RADIO LTD
Queensway, Enfield, Middx tel: Howard 1171

HEADLAND ENGINEERING DEVELOPMENTS LTD
45 Lower Marsh, London, SE1
tel: Waterloo 7752

HEARSON & CO LTD, CHARLES
68 Willow Walk, Bermondsey, London, SE1
tel: Bermondsey 4494

HEAT TRANSFER LTD
30 Church St, Croydon, Surrey tel: 7273

HEATHER FILTERS LTD
28 St. James's Place, London, SW1
tel: Hyde Park 7588

HBC COMPRESSORS & ENGINES LTD
Levis Works, Stechford, Birmingham, 33
tel: Stechford 2238

HELVETIA LEATHER CO LTD
Turnpike Works, Langham Rd, London, N15
tel: Bowes Park 5422

HENDREY RELAYS LTD
Bath Rd, Slough, Bucks tel: Burnham 609

HEENAN & FROUDE LTD
Worcester Eng Works, Worcester tel: 3461

HERBERT LTD, ALFRED
Coventry, Warws tel: Coventry 88781

HERBERT LTD, EDWARD G
Atlas Works, Levenshulme, Manchester, 19
tel: Rusholme 4176

HICK, HARGREAVES & CO LTD
Soho Ironworks, Bolton, Lancs tel: Bolton 1373

HIFI LTD
Derry Works, Derry Street, Brierley Hill, Staffs
tel: Brierley Hill 7604

HIGH PRESSURE COMPONENTS LTD
Sunflex Works, Culham Mill Rd, West Drayton, Middx tel: 2226

HIGGS MOTORS LTD
Halford Road, Birmingham, 6
tel: Birchfields 4545

HILGER & WATTS LTD
98 St Pancras Way, London, NW1
tel: Gulliver 5636

HILLMAN ELECTRIC MOTORS LTD
2–3 Northwold Bdgs, Northwold Rd, London, N16
tel: Amherst 5274

HILTON ELECTRIC CO LTD
52 Paul St, Wolverhampton tel: 22783

HIRST ELECTRONIC LTD
Gatwick Rd, Crawley, Sussex tel: Crawley 2166

HIVAC LTD
Stonefield Way, Victoria Rd, South Ruislip, Middx
tel: Ruislip 3366

HML (ENGINEERING) LTD
466 Edgware Rd, London, W2
tel: Paddington 0022

HOBSON LTD, H. M
Fordhouses, Wolverhampton
tel: Fordhouses 2266

HODGKINSON (SALFORD) LTD, JAMES
Ford Lane Works, Pendleton, Salford, 6
tel: Pendleton 1491

HOFFMANN MANUFACTURING CO LTD
Chelmsford, Essex tel: Chelmsford 3151

HOLIDAY & HEMMERDINGER LTD
74–78 Hardman St, Deansgate, Manchester, 3
tel: Deansgate 4121

HOLMAN BROS LTD
Camborne, Cornwall tel: Camborne 2275

HOLMES & CO LTD, W. C
Turnbridge, Huddersfield, Yorks tel: 5280

HONEYWELL CONTROLS LTD
Ruislip Road East, Greenford, Middx
tel: Waxlow 2333

HOOVER LTD
Somervell St, Cambuslang, Lanarks
tel: Cambuslang 1191

HOPKINSONS LTD
Huddersfield, Yorks tel: Huddersfield 3469

HOWDEN & CO LTD, JAMES
195 Scotland St, Glasgow, C5 tel: South 2131

HOWELL & CO LTD, V. G
Crown St, Wolverhampton
tel: Wolverhampton 26171

HUNT & MITTON LTD
Oozells Street North, Birmingham, 1
tel: Midland 0393

HUNT (CAPACITORS) LTD, A. H
Bendon Valley, Garratt Lane, London, SW18
tel: Battersea 1083

HUNTING AIRCRAFT LTD
Luton Airport, Beds tel: Luton 6060

HUTCHEON DUTHIE & SON LTD, R
18 David Rd, Poyle Trading Estate, Colnbrook, Bucks tel: 406

HYDRAULIC RECORDING INSTRUMENTS LTD
London Rd, Burgess Hill, Sussex
tel: Burgess Hill 3058

HYDRAULICS & PNEUMATICS LTD
Villiers St, Wolverhampton
tel: Wolverhampton 24456

HYMATIC ENGINEERING CO LTD, THE
Glover St., Redditch, Worcs tel: Redditch 743

IBM (UNITED KINGDOM) LTD
101 Wigmore St, London, W1 tel: Welbeck 6600

ICKNIELD ENGINEERING CO, THE
Icknield Way, Letchworth, Herts
tel: Letchworth 1706

IGRANIC ELECTRIC CO LTD
Bedford tel: Bedford 66261

ILFORD LTD
Ilford, Essex tel: Ilford 3000

IMPERIAL CHEMICAL INDUSTRIES LTD
Millbank, London, SW1 tel: Victoria 4444

INA NEEDLE BEARINGS LTD
34 Fitzroy Sq, London, W1 tel: Museum 3161

INCANDESCENT HEAT CO LTD
Cornwall Rd, Smethwick 40, Staffs tel: 2121

INDUSTRIAL PYROMETER CO LTD, THE
66–76 Gooch St, Birmingham, 5 tel: Midland 3511

INDUSTRIAL SOUND EQUIPMENT LTD
141 High St, Brentford, Middx tel: Ealing 1413

INDUSTRIAL TECHNICS (SOUTHAMPTON) LTD
Empress Rd, Southampton tel: 21435

INFRA RED DEVELOPMENT CO LTD, THE
11 Broadwater Rd, Welwyn Garden City, Herts
tel: Welwyn Garden 5591

INGELBURN PRODUCTS LTD
Wynyard Works, Malmesbury, Wilts
tel: Malmesbury 2297

INGERSOLL-RAND CO LTD
165 Queen Victoria St, London, EC4
tel: Central 5681

INNES & CO (DARLINGTON) LTD
11 Tubwell Row, Darlington tel: 4316

INSTRUMENT INSTALLATIONS LTD
20 Kensington Church St, London, W8
tel: Western 4118

INSTRUMENTS & CONTROLS LTD
Sandiway Place, Manchester Rd, Altrincham
tel: Altrincham 1393

INTEGRA, LEEDS & NORTHRUP LTD
183 Broad St, Birmingham, 15 tel: Midland 1453

INTEGRAL LTD
Birmingham Rd, Wolverhampton tel: 24984

INTERNATIONAL ENGINEERING CONCESSIONAIRES LTD
39 Parliament St, London, SW1
tel: Trafalgar 3386

INTERMIT LTD
44 Bradford St, Birmingham, 5 tel: Midland 7961

IONIC INSTRUMENTS (LONDON) LTD
317 Euston Rd, London, NW1 tel: Euston 5592

IPSCOL LTD
The Shipyard Estate, Hythe, Hants
tel: Hythe 2231

ISENTHAL & CO LTD
Ducon Works, Victoria Rd, London, W3
tel: Acorn 3904

ISOTOPE DEVELOPMENTS LTD
Beenham Grange, Aldermaston Wharf, Reading
tel: Woolhampton 451

IV PRESSURE CONTROLLERS LTD
683 London Rd, Isleworth, Middx
tel: Hounslow 7273

JACKSON & BRADWELL LTD
32 Paradise St, Birmingham, 1 tel: Midland 4770

JD ELECTRONICS (BIRMINGHAM) LTD
Leafield, Corsham, Wilts tel: Hawthorn 430

JENNINGS ORGAN CO LTD
Unity Works, Dartford, Kent tel: Dartford 4414

JOBLING & CO LTD, JAMES A
Wear Glass Works, Sunderland tel: 2082

JOHNSON, MATTHEY & CO LTD
78–83 Hatton Garden, London, EC1
tel: Holborn 6989

JONES & ATTWOOD LTD
Titan Works, Stourbridge, Worcs
tel: Stourbridge 5106

JONES & STEVENS LTD
Long Lane, Littlemore, Oxford tel: Oxford 77912

JONES, TATE & CO LTD
Victory Works, East Parade, Bradford tel: 28348

JOYCE, LOEBL & CO LTD
Vine Lane, Newcastle-on-Tyne, 1
tel: Newcastle 26985

JV RADIO & TELEVISION LTD
Brunswick Works, Brunswick Rd, Cattedown, Plymouth, Devon tel: Plymouth 64797

KANDEM ELECTRICAL LTD
711–715 Fulham Rd, London, SW6
tel: Renown 2387

KASAMA ELECTRONICS LTD
10 Northwold Rd, London, N16
tel: Stamford Hill 3513

KAY & CO (ENGINEERS) LTD
Blackhorse St, Bolton, Lancs tel: 197

KDG INSTRUMENTS LTD
Manor Royal, Crawley, Sussex tel: 25151

KEELAVITE ROTARY PUMPS & MOTORS LTD
Allesley, Coventry tel: Meriden 441

KEITH BLACKMAN LTD
Mill Mead Rd, Tottenham, London, N17
tel: Tottenham 4522

KELVIN & HUGHES LTD
2 Caxton St, London, SW1 tel: Abbey 7333

KENBAR ELECTRICAL CO LTD
Forsyth Rd, Sheerwater, Woking, Surrey
tel: Woking 5060

KENDALL & MOUSLEY LTD
18 Melville Rd, Edgbaston, Birmingham, 16
tel: Edgbaston 3321

KENT LTD, GEORGE
Biscot Rd, Luton, Beds tel: 2440

KENTON LABORATORIES LTD
4 Tottenham Mews, London, W1
tel: Museum 8105

KERRY'S (ULTRASONICS) LTD
Tonbridge Rd, Harold Hill, Romford, Essex
tel: Ingrebourne 41121

KERSHAW & SONS, A
200 Harehills Lane, Leeds, 8 tel: Leeds 44601

KETAY LTD
Eddes Ho, Eastern Avenue West, Romford, Essex
tel: Seven Kings 6050

KINGSLAND ENGINEERING CO LTD
25 Hackney Rd, London, E2 tel: Shoreditch 5365

KINGSTON CONTROL SYSTEMS LTD
Empire Chambers, Richmond Rd, Kingston, Surrey tel: 6808

KLB ELECTRIC LTD
16 Heneage Lane, Bevis Marks, London, EC3
tel: Avenue 1633

KLAXON LTD
49 Upper Brook St, London, W1
tel: Mayfair 9020

KLÖCKNER-MOELLER ENGLAND LTD
7 Charterhouse Bldgs, Goswell Rd, London, EC1
tel: Clerkenwell 0778

KNITTED MESH MANUFACTURING CO
36 Victoria St, London, SW1 tel: Abbey 2684

KODAK LTD
61-65 Kingsway, London, WC2 tel: Holborn 7841

LABGEAR LTD
Willow Place, Cambridge tel: 2494

LABORATORY EQUIPMENT (LONDON) LTD
18 Dames Rd, London, E7 tel: Maryland 4334

LACY-HULBERT & CO LTD
Boreas Works, Beddington, Croydon, Surrey
tel: Croydon 5504

LANCASHIRE DYNAMO & CRYPTO LTD
Trafford Park, Manchester, 17
tel: Trafford Park 2161

LANCASHIRE DYNAMO ELECTRONIC PRODUCTS LTD
Rugeley, Staffs tel: Rugeley 371

LANCASHIRE DYNAMO NEVELIN LTD
Hurst Green, Oxted, Surrey tel: Oxted 1450

LAND PYROMETERS LTD
Colonial Works, Queens Rd, Sheffield, 2
tel: 28451

LANG PNEUMATIC LTD
Birmingham Rd, Wolverhampton tel: 25221

LANGDALE ENGINEERING CO
Langdale Rd, Barnsley, Yorks tel: 4155

LANGLEY LONDON LTD
Kelvin Way, Crawley, Sussex tel: 681

LAURENCE, SCOTT & ELECTROMOTORS LTD
Norwich tel: Norwich 28333

LAYCOCK ENGINEERING LTD
Victoria Works, Millshouses, Sheffield, 8
tel: 74411

LEAK & CO LTD, H. J
Brunel Rd, Westway Factory Estate, London, W3
tel: Shepherds Bush 1173

LE CARBONE (GREAT BRITAIN) LTD
Portslade, Sussex tel: Hove 48268

LEE PRODUCTS (GT BRITAIN) LTD
Elpico Ho, Gt Eastern St, London, EC2
tel: Bishopsgate 0444

LEECH (ROCHESTER) LTD
277 High St, Rochester, Kent tel: Chatham 4155

LEEDS ENGINEERING & HYDRAULIC CO LTD, THE
Union Crane Works, Rodley, Leeds
tel: Pudsey 2859

LEEDS METER CO LTD, THE
Armley, Leeds, 12 tel: 38034

LELAND INSTRUMENTS LTD
22 Millbank, London, SW1 tel: Victoria 3243

LEVIS LTD
Stechford, Birmingham, 33 tel: Stechford 2238

LEWIS ELECTRIC MOTORS (MAIDENHEAD) LTD
Moor Works, Blackamoor Lane, Maidenhead, Berks tel: 3945

LEYBOLD VACUUM SALES LTD
27 Broadwick St, London, W1 tel: Gerrard 9641

LINCOLN ELECTRIC CO LTD
Welwyn Garden City, Herts
tel: Welwyn Garden 4581

LINFORD ENGINEERING CO LTD
93a Baker St, Birmingham, 11 tel: Victoria 0140

LINTRONIC LTD
149 Strand, London, WC2
tel: Covent Garden 1694

LION ELECTRONIC DEVELOPMENTS LTD
Lion Works, Hanworth Trading Estate, Feltham, Middx tel: Feltham 6661

LIQUID SYSTEMS LTD
7 Union Rd, Croydon, Surrey
tel: Thornton Heath 3221

LIQUIDS CONTROL LTD
Imperial Works, Braganza St, London, SE17
tel: Reliance 6144

LIVINGSTON LABORATORIES LTD
Retcar St, Dartmouth Park Hill, London, N19
tel: Archway 6251

LMK MANUFACTURING CO LTD
Harlequin Avenue, Great West Rd, Brentford, Middx tel: Ealing 1858

LOCK & CO LTD, A. M
105 Crompton St, Chadderton, Oldham, Lancs
tel: Oldham Main 2578

LOCKHEED INDUSTRIAL HYDRAULICS
(See Automotive Products Co Ltd)

LONDEX LTD
207 Anerley Rd, London, SE20
tel: Sydenham 3111

LONDON TRANSFORMER PRODUCTS LTD
Cobbold Estate, London, NW10
tel: Willesden 6681

LONDON V ROPE DRIVE CO
Clifton Terrace, Finsbury Park, London, N4
tel: Archway 4212

LOWE (LIFTS) LTD, HENRY
Falcon Lift Works, Royton, Oldham
tel: Oldham 3605

LOWTHER MANUFACTURING CO, THE
Lowther Ho, St Mark's Rd, Bromley, Kent
tel: Ravensbourne 5225

LUCAS (ELECTRICAL) LTD, JOSEPH
Great King St, Birmingham, 19
tel: Northern 5252

LYDIATE ASH LABORATORIES
Lydiate Ash, Bromsgrove, Worcs tel: Aubery 168

LYONS LTD, CLAUDE
76 Old Hall St, Liverpool, 3 tel: Central 4641

MCDONALD LTD, L. B
49 Clifton St, London, EC2 tel: Bishopsgate 1474

MCKELLEN AUTOMATION LTD
122 Seymour Grove, Manchester, 16
tel: Chorlton 5366

MADAN & CO LTD, CHARLES S
Vortex Works, Atlantic St, Altrincham, Ches
tel: 2702

MACFARLANE ENGINEERING CO LTD
Netherlee Rd, Glasgow, S4 tel: Merrylee 2255

MAGNET ENGINEERING CO, THE
52 Seel St, Liverpool, 1 tel: Royal 1409

MAGNETIC CONTROLS LTD
24 Ritherdon Rd, London, SW17
tel: Balham 0399

MAGNETIC COATINGS LTD
25 Dashwood Trading Estate, Larch Rd, London, SW12

MAGNETIC DEVICES LTD
Exning Rd, Newmarket, Suffolk tel: 3181

MAGNETIC EQUIPMENT CO LTD, THE
Lake Works, Wicor, Portchester, Hants
tel: Cosham 75025

MAGNETIC & ELECTRICAL ALLOYS LTD
Burnbank, Hamilton, Lanarks tel: 932

MAGNETIC VALVE CO LTD, THE
28 St James's Place, London, SW1
tel: Hyde Park 7588

MALLORY BATTERIES LTD
Rainham Works, Rainham Road South, Dagenham, Essex tel: Dominion 2111

MANCUNA ENGINEERING LTD
Denton, Manchester tel: Denton 3965

MANCHESTER WATER METER CO LTD, THE
Tipping St, Manchester, 12 tel: Ardwick 3730

MARCONI INSTRUMENTS LTD
Longacres, St. Albans, Herts tel: 56161

MARCONI INTERNATIONAL MARINE COMMUNICATION CO LTD, THE
Marconi Ho, Strand, London, WC2
tel: Covent Garden 1234

MARCONI'S WIRELESS TELEGRAPH CO LTD
Marconi Ho, Chelmsford, Essex tel: 3221

MARLEY & CO LTD, W. H
105 High Rd, London, N11 tel: Enterprise 5234

MARSTON EXCELSIOR LTD
Wobaston Rd, Fordhouses, Wolverhampton
tel: Fordhouses 3361

MARTINDALE ELECTRIC CO LTD
Westmorland Rd, London, NW9
tel: Colindale 8642

MARTONAIR LTD
Parkshot, Richmond, Surrey tel: Richmond 3348

MATTHEWS & YATES LTD
Cyclone Works, Swinton, Manchester
tel: Swinton 2273

MAWDESLEY'S LTD
Dursley, Glos tel: 2386

MB METALS LTD
Vale Works, Portslade, Sussex tel: Hove 48623

M & C SWITCHGEAR LTD
Kelvinside Works, Kirkintilloch, Glasgow
tel: Kirkintilloch 2216

MEAD & PHASEY LTD
Princess St, Bexleyheath, Kent tel: 2876

MEADOWS LTD, HENRY
Fallings Park, Wolverhampton tel: 31921

MEASURE-METERS CO LTD
Milltown St, Radcliffe, Manchester
tel: Radcliffe 2675

MEASUREMENT LTD
Tameside Works, Dobcross, Oldham, Lancs
tel: Delph 284

MEASURING INSTRUMENTS (PULLIN) LTD
Electrin Works, Winchester St, Acton, W3
tel: Acorn 4561

MECHANICAL & ELECTRONIC PRODUCTS (LONDON) LTD
9 New Cavendish St, London, W1
tel: Welbeck 1421

MECHANISM LTD
Gyro Works, George St, Croydon, Surrey
tel: Croydon 3426

MELVIN BROS LTD
72-78 Causewayside, Edinburgh tel: 41980

MERCER LTD, THOMAS
Eyrwood Rd, St Albans, Herts
tel: St Albans 55313

MERVYN INSTRUMENTS
Copse Rd, St Johns, Woking, Surrey
tel: Woking 2091

MERVYN SOUND & VISION CO LTD
(See Mervyn Instruments)

METALASTIK LTD
Evington Valley Rd, Leicester tel: Leicester 37281

METERING PUMPS LTD
21 The Mall, Ealing, W5 tel: Ealing 4024

METROPOLITAN ENGINEERING CO LTD, THE
47 Whitechapel High St, London, E1
tel: Bishopsgate 0451

METRIX INSTRUMENTS LTD
(Represented by Solartron Electronic Group Ltd)

METROPOLITAN-VICKERS ELECTRICAL CO LTD
Trafford Park, Manchester, 17
tel: Trafford Park 2431

MICKELWRIGHT LTD
Bridgewater Rd, Alperton, Wembley, Middx
tel: Wembley 0147

MICROCELL ELECTRONICS
56 Kingsway, London, WC2 tel: Chancery 3424

MICROWAVE INSTRUMENTS LTD
West Chirton Industrial Estate, North Shields, Northumberland tel: 3606

MIDLAND ELECTRIC MANUFACTURING CO LTD
MEM Works, Reddings Lane, Birmingham, 11
tel: Acocks Green 1695

MIDLAND PNEUMATIC LTD
New Cross, Wolverhampton tel: 31069

MILLETT, LEVENS (INSTRUMENTS & ENGINEERING) LTD
Barnet By-Pass, Stirling Corner, Borehamwood, Herts tel: Elstree 2871

MILLS & CO (LLANIDLOES) LTD, JOHN
Railway Foundry, Llanidloes, Montgomeryshire
tel: 371

MILNE & LONGBOTTOM LTD
Elm Works, Mere Lane, Rochdale
tel: Rochdale 48331

MINERVA DETECTOR CO LTD, THE
Lower Mortlake Rd, Richmond, Surrey
tel: Richmond 6431

MINE SAFETY APPLIANCES CO LTD
Queenslie Industrial Estate, Glasgow, E3
tel: Shettleston 3421

MINIATURE BEARINGS LTD
39 Parliament St, Westminster, London, SW1
tel: Trafalgar 3386

MORGAN CRUCIBLE CO LTD, THE
Battersea Church Rd, London, SW11
tel: Battersea 8822

MODERN AUTOMATIC TELEPHONES LTD
101 Tottenham Court Rd, London, W1
tel: Museum 9192

MOLLART ENGINEERING CO LTD
Kingston By-Pass, Surbiton, Surrey
tel: Elmbridge 3352

MONCRIEFF LTD, JOHN
Perth, Scotland tel: Perth 711

MORECAMBE ELECTRICAL EQUIPMENT CO LTD
Westgate Works, Morecambe, Lancs
tel: Morecambe 3474

MORGAN CRUCIBLE CO LTD, THE
Battersea Church Rd, London, SW11
tel: Battersea 8822

MORRIS ELECTRICAL ENGINEERING CO LTD, JOHN
Vulcan Rd, Bilston, Staffs tel: Bilston 41237

MORRISON, MARSHALL & HILL LTD
44-45 Tower Hill, London, EC3 tel: Royal 1461

MOTOR ELECTRICS CO
Crown Lane, Marlow, Bucks tel: Marlow 1005

MSS RECORDING CO LTD
Poyle Farm, Colnbrook, Bucks tel: 2431

MTE CONTROL GEAR LTD
Leigh-on-Sea, Essex tel: Eastwood 54284

MUDIE'S ELECTRICAL CO LTD
Shaftmoor Lane, Birmingham, 28
tel: Springfield 2274

MUIRHEAD & CO LTD
Beckenham, Kent tel: 4888

MULLARD LTD
Mullard Ho, Torrington Place, London, WC1
tel: Langham 6633

MULLARD EQUIPMENT LTD
(See Mullard Ltd)

MULTI-RECORDINGS LTD
27 Craven St, London, WC2 tel: Trafalgar 6655

MULTITONE ELECTRIC CO LTD
25 Dover St, London, W1 tel: Hyde Park 9977

MUNRO LTD, R. W
Bounds Green, London, N11 tel: Enterprise 4422

MUREX LTD
Rainham, Essex tel: Rainham 3322

MURPHY RADIO LTD
Welwyn Garden City, Herts tel: Welwyn 3434

NAGARD LTD
18 Avenue Rd, Belmont, Surrey tel: Vigilant 9161

NALDER BROS & THOMPSON LTD
Dalston Lane Works, London, E8
tel: Clissold 2365

NASH & THOMPSON LTD
Oakcroft Rd, Chessington, Surrey
tel: Elmbridge 5252

NEGRETTI & ZAMBRA LTD
122 Regent St, London, W1 tel: Regent 3406

NERA ELECTRICAL CO
330 Kennington Rd, London, SE11
tel: Reliance 4261

NEW ELECTRONIC PRODUCTS LTD
360 Kennington Rd, London, SE11
tel: Reliance 5161

NEW PROCESS WELDERS LTD
Nelson Place, City Rd, London, N1
tel: Clerkenwell 1381

NEW WESTERN (ENGINEERING) LTD
136 Meadow Lane, Leeds, 11 tel: 23358

NEWAGE (MANCHESTER) LTD
Crossley St, Gorton, Manchester, 18
tel: East 2071

NEWBOLD & BULFORD LTD
Enbeeco Ho, Roger St, London, WC1
tel: Chancery 5614

NEWBURY DIESEL CO LTD
King's Rd, Newbury, Berks tel: Newbury 528

NEWMARKET TRANSISTOR CO LTD
Exning Rd, Newmarket, Suffolk tel: 3381

NEWPORT INSTRUMENTS (SCIENTIFIC & MOBILE) LTD
Newport Pagnell, Bucks tel: Newport Pagnell 401

NEWTON VICTOR LTD
132 Long Acre, London, WC2
tel: Covent Garden 0861

NGN ELECTRICAL LTD
Nassau Mills, Cawdor St, Patricroft, Manchester
tel: Eccles 1643

NICKOLS AUTOMATICS LTD
7 Carlisle Rd, London, NW9 tel: Colindale 6141

NICOLSON (SCIENTIFIC INSTRUMENTS) LTD, W. B
Thornliebank Industrial Estate, Glasgow
tel: Giffnock 2241

NIFE BATTERIES
Redditch, Worcs tel: Redditch 157

NORGREN LTD, C. A
Shipston-on-Stour, Warws tel: 106

NORMALAIR LTD
West Hendford, Yeovil, Somerset tel: Yeovil 1100

NORMAND ELECTRICAL CO LTD
North St, Clapham Common, London, SW4
tel: Macaulay 3211

NORTHEY ROTARY COMPRESSORS LTD
Alder Rd, Parkstone, Poole, Dorset
tel: Parkstone 4900

NOTTINGHAM THERMOMETER CO LTD, THE
63 Mansfield Rd, Nottingham tel: 45815

NSF LTD
Ingrow Bridge Works, Keighley, Yorks tel: 4221

NSR MANUFACTURING LTD
394 Northolt Rd, South Harrow, Middx tel: Byron 1863

NUCLEAR ENGINEERING LTD
Greenwich Metal Works, London, SE7 tel: Greenwich 3232

NUCLEAR ENTERPRISES (GB) LTD
Bankhead Medway, Edinburgh, 11 tel: Craiglockhart 4513

NUCLEONIC & RADIOLOGICAL DEVELOPMENTS LTD
22 Marshgate Lane, London, E15 tel: Maryland 4577

OERTLING LTD, L
Cray Valley Rd, St Mary Cray, Orpington, Kent tel: Orpington 25771

OIL FEED ENGINEERING CO LTD
18 Denbigh St, London, SW1 tel: Victoria 9807

OLDHAM & SON LTD
Denton, Nr Manchester tel: Denton 2431

OPPERMAN LTD, S. E
Stuart Works, Stirling Corner, Borehamwood, Herts tel: Elstree 2021

OPTICAL WORKS LTD
32 The Mall, Ealing, W5 tel: Ealing 5678

OSWALDS & RIDGWAY LTD
Station Avenue, Kew Gardens, Surrey tel: Richmond 2336

OTTER CONTROLS LTD
Otter's Ole, Buxton, Derbys tel: Buxton 650

OTTERMILL SWITCHGEAR LTD
The Otter Mill, Ottery St Mary, Devon tel: 264

OTTWAY & CO LTD, W
Orion Works, Northfield Avenue, Ealing, W13 tel: Ealing 5844

OZONAIR ENGINEERING CO LTD
Ozonair Works, The Esplanade, Rochester, Kent tel: Chatham 45011

PAGE ENGINEERING CO
Page Works, Forge Lane, Green St, Sunbury-on-Thames, Middx. tel: Sunbury 2642

PAINTON & CO LTD
Kingsthorpe, Northampton tel: 32354

PALATINE TOOL & ENGINEERING CO (SURBITON) LTD
64–76 Brighton Rd, Surbiton, Surrey tel: Elmbridge 7261

PALMER LTD, G. A STANLEY
Maxwell Ho, Arundel St, London, WC2 tel: Temple Bar 1610

PAM LTD
Merrow, Guildford, Surrey tel: Guildford 2211

PANAX EQUIPMENT LTD
173 London Rd, Mitcham, Surrey tel: Mitcham 2006

PANELLIT LTD
70 Dudden Hill Lane, London, NW10 tel: Willesden 5141

PAR LTD
95 Talbot St, Nottingham tel: Nottingham 46505

PARKINSON AND COWAN INSTRUMENTS
Terminal Ho, Grosvenor Gardens, London, SW1 tel: Sloane 0111

PARMEKO LTD
Percy Rd, Aylestone Park, Leicester tel: 32287

PARSONS & CO LTD, C. A
Heaton Works, Newcastle-on-Tyne, 6 tel: Newcastle 56101

PARSONS & CO LTD, S
Young St, Bradford, Yorks tel: 45494

PARTRIDGE, WILSON & CO LTD
Davenset Electrical Works, Evington Valley Rd, Leicester tel: 37291

PAUL LTD, K. S
Great Western Trading Estate, Park Royal Rd, London, NW10 tel: Elgar 3751

PAYNE & GRIFFITHS LTD
Tudor Works, Windmill Lane, Smethwick, Staffs tel: Smethwick 1518

P & B ENGINEERING CO LTD
Crompton Way, Crawley, Sussex tel: 1004

PELL CONTROL LTD, OLIVER
Cambridge Row, London, SE18 tel: Woolwich 1422

PERKIN-ELMER A. G
160 Cheapside, London, EC2 tel: Monarch 8177

PERL CONTROLS LTD
Gatwick Rd, Crawley, Sussex tel: 25115

PETO & RADFORD
137 Victoria St, London, SW1 tel: Tate Gallery 9212

PETO SCOTT ELECTRICAL INSTRUMENTS LTD
Weybridge Trading Estate, Addlestone Rd, Weybridge, Surrey tel: 4271

PETTERS LTD
Staines, Middx tel: 1122

PHILLIPS CONTROL (GB) LTD
273 Farnborough Rd, Farnborough, Hants tel: 1120

PHILLIPS & BONSON LTD
Imperial Ho, Dominion St, Moorgate, London, EC2 tel: Monarch 5481

PILLIN LTD, JOHN B
Hartlepools Industrial Estate, Hartlepools, Co Durham tel: Hartlepools 3115

PILOT RADIO LTD
31–37 Park Royal Rd, London, NW10 tel: Elgar 7353

PLANER LTD, G. V
Hanworth Trading Estate, Hampton Road West, Feltham Middx tel: Feltham 3399

PLANNAIR LTD
Windfield Ho, Epsom Rd, Leatherhead, Surrey tel: 4091

PLATON LTD, G. A
323a Whitehorse Rd, Croydon, Surrey tel: Thornton Heath 1631

PLENTY & SON LTD
Eagle Ironworks, Newbury, Berks tel: 2363

PLESSEY CO LTD, THE
Ilford, Essex tel: Ilford 3040

PLESSEY NUCLEONICS LTD
Weedon Rd, Northampton tel: 4966

PNEUSPEED LTD
127 Edinburgh Avenue, Trading Estate, Slough, Bucks tel: 23193

PORTOGRAM RADIO ELECTRICAL INDUSTRIES LTD
Preil Works, St Rule St, London, SW8 tel: Macaulay 2246

POULTEN, SELFE & LEE LTD
Wickford, Essex tel: Wickford 3246

POWER AUXILIARIES LTD
Kembrey St, Swindon, Wilts tel: 6211

POWER CONTROLS LTD
Exning Rd, Newmarket, Suffolk tel: 3181

POWER EQUIPMENT CO LTD
Kingsbury Works, Kingsbury Rd, London, NW9 tel: Colindale 6196

POWER FLEXIBLE TUBING CO LTD, THE
Derby Works, Vale Rd, London, N4 tel: Stamford Hill 6696

POWER JACKS LTD
Maylands Avenue, Hemel Hempstead, Herts tel: Boxmoor 3800

POWER JETS (RESEARCH & DEVELOPMENT) LTD
25 Green St, London, W1 tel: Mayfair 7801

POWERS SAMAS ACCOUNTING MACHINES LTD
Holborn Bars, London, EC1 tel: Chancery 3311

PRATT PRECISION HYDRAULICS LTD
Craven Edge Works, Halifax, Yorks tel: 66371

PRECISION TOOL & INSTRUMENT CO LTD, THE
353 Bensham Lane, Thornton Heath, Surrey tel: 2778

PREMIER COOLER & ENGINEERING CO LTD
Pathfield, Station Rd, Shalford, Guildford tel: 5221

PRENTICE LTD
Gelderd Rd, Leeds, 12 tel: 638777

PRESSURE CONTROL LTD
Davis Rd, Chessington, Surrey tel: Elmbridge 7460

PRINGLE & SONS (LONDON) LTD, ROBERT
36–42 Clerkenwell Rd, London, EC1 tel: Clerkenwell 2341

PRINTED CIRCUITS LTD
Stirling Corner, Barnet By-Pass, Borehamwood, Herts tel: Elstree 2871

PRINTED CIRCUIT DEVELOPMENTS LTD
Guildford Rd, Bisley, Surrey tel: Brookwood 2200

PRIOR & CO LTD, W. R
Northgate End, Bishop's Stortford, Herts tel: Bishop's Stortford 437

PRITCHETT & GOLD AND EPS COMPANY LTD
137 Victoria St, London, SW1 tel: Tate Gallery 9212

PROCESS CONTROL GEAR LTD
44 Lattimore Rd, St Albans, Herts tel: 57738

PULLIN & CO LTD, R. B
Phoenix Works, Great West Rd, Brentford, Middx tel: Ealing 0011

PULSOMETER ENGINEERING CO LTD, THE
Nine Elms Iron Works, Reading tel: 67182

PYE & CO LTD, W. G
Granta Works, Newmarket Rd, Cambridge tel: 54411

PYE LTD (Industrial TV Division)
9 Upper Berkeley St, London, W1 tel: Ambassador 3044

PYROTENAX LTD
Hedgeley Rd, Hebburn, Co Durham

QUALITY BEARINGS LTD
220 Bedford Avenue, Slough, Bucks tel: 22228

QR TELEVISION INSTALLATIONS LTD
118 Sheen Rd, Richmond, Surrey tel: Richmond 3040

RACAL ENGINEERING LTD
Western Rd, Bracknell, Berks tel: 941

RADENITE BATTERIES LTD
Coventry, Warws tel: Coventry 89044

RADIO-AIDS LTD
29 Market St, Watford, Herts

RADIOCHEMICAL CENTRE, THE
Amersham, Bucks tel: Little Chalfont 2278

RADIO RESISTOR CO LTD, THE
50 Abbey Gardens, London, NW8 tel: Maida Vale 5522

RADIOVISOR PARENT LTD
Stanhope Works, High Path, London, SW19 tel: Cherrywood 3351

RAMSEY ENGINEERING CO LTD
37 Ramsey Rd, London, W3 tel: Acorn 7430

RANSOME & MARLES BEARING CO LTD
Newark-on-Trent, Notts tel: Newark 456

RANK CINTEL LTD
Worsley Bridge Rd, London, SE26 tel: Hither Green 4600

RAPID MAGNETIC MACHINES LTD
Lombard St, Birmingham, 12 tel: Victoria 1137

REAVELL & CO LTD
Ranelagh Works, Ipswich tel: Ipswich 2124

RECORD ELECTRICAL CO LTD, THE
Broadheath, Altrincham, Ches tel: 3221

RECORDING DEVICES LTD
95 Villiers Rd, London, NW2 tel: Willesden 6678

REDIFON LTD
Broomhill Rd, London, SW18 tel: Vandyke 7281

REED BROS (ENGINEERING) LTD
Replant Works, Woolwich Industrial Estate, London, SE18 tel: Woolwich 7611

REID & SIGRIST LTD
Braunstone Works, Braunstone, Leicester tel: 88101

REILLY ENGINEERING LTD
Walnut Tree Close, Guildford, Surrey tel: 67201

RESEARCH & CONTROL INSTRUMENTS LTD
207 Kings Cross Rd, London, WC1 tel: Terminus 8444

RESEARCH UTILITIES LTD
Laker Estate, Kent House Lane, Beckenham, Kent tel: Sydenham 6223

REOSOUND ENGINEERING & ELECTRICAL CO
Reosound Works, Coleshill Rd, Sutton Coldfield tel: Sutton Coldfield 4685

RESISTANCES LTD
30 Oxford Rd, Finsbury Park, London, N4 tel: Archway 2155

REYNOLDS & BRANSON LTD
13 Briggate, Leeds tel: 33681

REYNOLDS, SON & WARDALE LTD, T. A
40–42 Percival St, London, EC1 tel: Clerkenwell 6127

REYROLLE & CO LTD, A
Hebburn, Co Durham tel: 32441

RHEOSTATIC CO LTD, THE
Farnham Road, Slough, Bucks tel: 23961

RICHARDSON & SONS LTD, R. J
Commercial St, Birmingham, 1 tel: Midland 2281

RICHARDSONS, WESTGARTH (HARTLEPOOL) LTD
Northumberland Engine Works, Wallsend-on-Tyne tel: Wallsend 63141

RIVLIN LTD, J
16–17 Brunswick St, Leeds, 2 tel: 31458

ROBEY & CO LTD
PO Box No 23, Globe Works, Lincoln tel: 21381

ROBINSON & PARTNERS LTD, F. C
Councillor Lane, Cheadle, Ches tel: Gatley 2469

ROLLASON AEROCESSORIES LTD
Croydon Airport, Surrey tel: Croydon 5151

ROLLS-ROYCE LTD
PO Box 31, Derby tel: 40341

ROSS, COURTNEY & CO LTD
Ashbrook Rd, London, N19 tel: Archway 1166

ROTAMETER MFG CO LTD, THE
330 Purley Way, Croydon, Surrey tel: 3816

ROTAX LTD
Willesden Junction, London, NW10 tel: Elgar 7777

ROVER GAS TURBINES LTD
Meteor Works, Lode Lane, Solihull, Warws tel: Sheldon 4242

RUBBER BONDERS LTD
Dunstable, Beds tel: 803

RUSTON & HORNSBY LTD
Sheaf Ironworks, Lincoln tel: 580

RYDER & CO (MANCHESTER) LTD, THOMAS
Commercial St Works, Manchester, 15 tel: Central 6753

RYE BEARINGS, CLAUDE
895–921 Fulham Rd, London, SW6 tel: Renown 6174

SALFORD ELECTRICAL INSTRUMENTS LTD
Peel Works, Silk St, Salford, 3, Lancs tel: Blackfriars 6688

SAMSON CONTROLS (LONDON) LTD
19 Borough High St, London, SE1 tel: Hop 0776

SAMWELL AND HUTTON
Delta Works, 54 Goodmayes Avenue, Ilford, Essex tel: Seven Kings 0342

SANDERS (ELECTRONICS) LTD, W. H
Gunnels Wood Rd, Stevenage, Herts tel: 981

SANGAMO WESTON LTD
Great Cambridge Rd, Enfield, Middx tel: Enfield 3434

SANTON LTD
Somerton Works, Newport, Mon tel: 71711

SARGROVE ELECTRONICS LTD
Alexandra Rd, Hounslow, Middx tel: Hounslow 0213

SAUNDERS-ROE LTD (Electronics Division)
East Cowes, Isle of Wight tel: Cowes 2211

SAUNDERS VALVE CO LTD
Cwmbran, Mon tel: Cwmbran 3081

SAUTER CONTROLS LTD
70 Dudden Hill Lane, London, NW10 tel: Willesden 6166

SAVAGE & PARSONS LTD
Otterspool Way, Watford By-Pass, Watford, Herts tel: 6071

SAVAGE LTD, W BRYAN
17 Stratton St, London, W1 tel: Grosvenor 1926

SAVERY PUMPS LTD, THOMAS
Newcomen Works, Bracebridge St, Birmingham, 6 tel: Aston Cross 1316

SCHRADER'S SON, A
829 Tyburn Rd, Birmingham, 24 tel: Erdington 2267

SCIENTIFIC & PROJECTIONS LTD
Government Bldgs, Kidbrooke Park Rd, London, SE3 tel: Lee Green 2112

SCIENTIFIC INSTRUMENTS (GLASGOW) LTD
154–156 Grovepark St, Glasgow, NW tel: Douglas 6621

SELAS GAS & ENGINEERING CO LTD
Selas Works, City Rd, Manchester, 15 tel: Central 2648

SEMICONDUCTORS LTD
Cheney Manor, Swindon, Wilts tel: 6421

SERVIS RECORDERS LTD
19 London Rd, Gloucester tel: Gloucester 24125

SERVOMEX CONTROLS LTD
Crowborough Hill, Jarvis Brook, Sussex tel: Crowborough 1247

SFIM (GREAT BRITAIN) LTD
220 Bedford Avenue, Slough, Bucks tel: 22228

SHACKMAN & SONS, D
Chiltern Works, Waterside, Chesham, Bucks tel: 8690

SHANDON SCIENTIFIC CO LTD
6 Cromwell Place, London, SW7 tel: Knightsbridge 1131

SHARP CONTROL GEAR LTD
Lount Works, Ashby-de-la-Zouch, Leics tel: Ashby 422

SHAW MOISTURE METERS
31 Market St, Bradford, Yorks tel: 24959

SHELL CHEMICAL CO LTD
15–17 Marlborough St, W1 tel: Gerrard 0666
SHIPTON & CO LTD, E
Ferndown Works, Pinner, Middx
tel: Pinner 1103
SHORT BROS & HARLAND LTD
Queen's Island, Belfast tel: 58444
SHORT, J. P
26 Lower Richmond Rd, London, SW15
tel: Putney 2667
SHORT & MASON LTD
280 Wood St, London, E17 tel: Coppermill 2203
SIEBE, GORMAN & CO LTD
Davis Rd, Chessington, Surrey
tel: Elmbridge 5900
SIEMENS EDISON SWAN LTD
155 Charing Cross Rd, London, WC2
tel: Gerrard 8660
SIEMENS-SCHUCKERT (GREAT BRITAIN) LTD
Gt West Rd, Brentford, Middx tel: Ealing 1171
SIFAM ELECTRICAL INSTRUMENT CO LTD
Leigh Court, Higher Lincombe Rd, Torquay
tel: 4547
SIGMA INSTRUMENT CO LTD
Letchworth, Herts tel: Letchworth 1845
SILENTBLOC LTD
Manor Royal, Crawley, Sussex tel: 2100
SILVERTOWN RUBBER CO LTD
Herga Ho, Vincent Sq, London, SW1
tel: Victoria 8323
SIMMONDS AEROCESSORIES LTD
Treforest, Pontypridd, Glam tel: Treforest 2211
SIMMONDS LTD, L. E
5 Byron Rd, Harrow, Middx tel: Harrow 2524
SIMMONS ELECTRICAL & WINDING CO LTD
Simpsons Rd, Bromley, Kent
tel: Ravensbourne 3594
SIMON LTD, HENRY
Cheadle Heath, Stockport, Ches tel: Gatley 3621
SIMON-CARVES LTD
Cheadle Heath, Stockport, Ches tel: Gatley 3600
SIMPLIFIX COUPLINGS LTD
Hargrave Rd, Maidenhead, Berks tel: 2271
SINEX ENGINEERING CO LTD
12 Rochester Row, London, SW1
tel: Victoria 7503
SKEFKO BALL BEARING CO LTD
Skefko Works, Luton, Beds tel: 4700
SLINGSBY & CO LTD, WALTER
Railway Works, Keighley, Yorks tel: 3749
SMALL ELECTRIC MOTORS LTD
Eagle Works, Churchfields Rd, Beckenham, Kent
tel: Beckenham 0066
SMITH & GRACE LTD
Thrapston, Kettering tel: Thrapston 109
SMITHS AIRCRAFT INSTRUMENTS LTD
Cricklewood Works, Edgware Rd, London, NW2
tel: Gladstone 3333
SMITHS INDUSTRIAL INSTRUMENTS LTD
Chronos Works, North Circular Rd, London, NW2
tel: Gladstone 1136
SMITHS JACKING SYSTEMS LTD
Jackall Works, Edgware Rd, London, NW2
tel: Gladstone 6671
SMITHS MOTOR ACCESSORIES LTD
50 Oxgate Lane, London, NW1
tel: Gladstone 8030
SMURTHWAITE ENGINEERING CO LTD
Ross Parade, Wallington, Surrey tel: 1982
SOLARTRON ELECTRONIC GROUP LTD, THE
Thames Ditton, Surrey tel: Emberbrook 5522
SOLUS-SCHALL LTD
15 Clipstone St, London, W1 tel: Museum 6342
"SOLUS" ELECTRONIC TUBES LTD, THE
15 Clipstone St, London, W1 tel: Museum 3121
SOUND SALES LTD
West St, Farnham, Surrey tel: 6461
SOUTH LONDON ELECTRICAL EQUIPMENT CO LTD
Lanier Works, Higher Green Lane, London, SE13
tel: Lee Green 4814
SOUTHERN INSTRUMENTS COMPUTER DIVISION
Frimley Rd, Camberley, Surrey tel: 2230
SPECK LTD, ROBERT
PO Box 2, Rickmansworth, Herts
tel: Chorley Wood 646
SPECTO LTD
Vale Rd, Windsor, Berks tel: 1241
SPENBOROUGH ENGINEERING CO LTD
Valley Works, Union Rd, Heckmondwike, Yorks
tel: 924
SPENCER-WEST LTD
Quay Works, North Quay, Gt Yarmouth
tel: Gt Yarmouth 3009
SPENCER COMPONENTS LTD (BOUGH & OSBORNE)
5 High St, Birmingham, 14 tel: Highbury 3155
SPERRY GYROSCOPE CO LTD
Gt West Rd, Brentford, Middx tel: Ealing 6771
SPIRAX-SARCO LTD
St George's Rd, Cheltenham tel: 3028
SPIRO BALL BEARING CO LTD
Regent St, Kettering tel: 2122
SQUARE D LTD
100 Aldersgate St, London, EC1
tel: Metropolitan 8646
SS ELECTRONICS LTD
Byron Rd, Harrow, Middx tel: Harrow 7744
STANDARD & POCHIN BROS LTD, THE
Evington Valley Rd, Leicester tel: 36114
STANDARD TELEPHONES & CABLES LTD
63 Aldwych, London, WC2 tel: Holborn 8765
STANLEY & CO LTD, W. F
New Eltham, London, SE9 tel: Eltham 3836
STANTON INSTRUMENTS LTD
119 Oxford St, London, W1 tel: Gerrard 7533

STEIN ATKINSON VICKERS HYDRAULICS LTD
60 Buckingham Palace Rd, London, SW1
tel: Sloane 7261
STERDY TELEPHONES LTD
180–182 Tottenham Court Rd, London, W1
tel: Museum 4414
STERLING INSTRUMENT CO LTD
Boden Works, Chard, Somerset tel: 2341
STILLITE PRODUCTS LTD
15 Whitehall, London, SW1 tel: Whitehall 0922
STONE CHANCE LTD
Gatwick Rd, Crawley, Sussex tel: 25251
STONEBRIDGE ELECTRICAL CO LTD, THE
6 Queen Anne's Gate, London, SW1
tel: Trafalgar 1444
STREAM-LINE FILTERS LTD
38 Ingate Place, London, SW8
tel: Macaulay 1011
STURTEVANT ENGINEERING CO LTD
Southern Ho, Cannon St, London, EC4
tel: Mansion House 0533
SUPERVENTS LTD (Dept. N)
Sidcup By-Pass, Sidcup, Kent
tel: Footscray 5661
SULLIVAN LTD, H. W
72 Leo St, London, SE15 tel: New Cross 3225
SUNVIC CONTROLS LTD
No 1 Factory, Temple Fields, Harlow, Essex
tel: 25271
SYKES INTERLOCKING SIGNAL CO LTD, W. R
26 Voltaire Rd, London, SW4 tel: Macaulay 3451
SYKES LTD, HENRY
Southwark St, London, SE1 tel: Hop 5321
TANGYES LTD
Cornwall Works, Smethwick, Staffs tel: 1181
TANNOY PRODUCTS LTD
348 Norwood Rd, London, SE27
tel: Gipsy Hill 1131
TAPE RECORDERS (ELECTRONICS) LTD
3 Fitzroy St, London, W1 tel: Museum 5563
TAYLOR CONTROLS LTD
75 Hale End Rd, London, E17
tel: Larkswood 3371
TAYLOR ELECTRICAL INSTRUMENTS LTD
Montrose Avenue, Slough, Bucks tel: 21381
TAYLOR, TAYLOR & HOBSON LTD
Stoughton Street Works, Leicester tel: 20134
TECALEMIT LTD
Plymouth, Devon tel: 62844
TECHNICAL CERAMICS LTD
Wood Burcote Way, Towcester, Northants
tel: 312
TECHNICAL SALES
32 Lupus St, London, SW1 tel: Victoria 5155
TECHNOGRAPH ELECTRONIC PRODUCTS LTD
(See Technograph Printed Circuits Ltd)
TECHNOGRAPH PRINTED CIRCUITS LTD
32 Shaftesbury Av, London, W1 tel: Gerrard 4532
TEDDINGTON REFRIGERATION CONTROLS LTD
Teddington Works, Sunbury-on-Thames, Middx
tel: 600
TEDDINGTON AIRCRAFT CONTROLS LTD
Cefn Coed, Nr Merthyr Tydfil, South Wales
tel: 666
TEDDINGTON INDUSTRIAL EQUIPMENT LTD
Teddington Works, Sunbury-on-Thames, Middx
tel: Sunbury 600
TELECOMMUNICATION INSTRUMENTS LTD
244a Southtown Rd, Great Yarmouth, Norfolk
tel: Great Yarmouth 4447
TELEDICTOR LTD
Birmingham Rd, Dudley, Worcs tel: 4655
TELEFLEX PRODUCTS LTD
Basildon, Essex tel: 22861
TELEFUSION (ENGINEERING) LTD
Teleng Works, Church Rd, Harold Wood, Romford, Essex tel: Ingrebourne 2901
TELEGRAPH CONSTRUCTION & MAINTENANCE CO LTD, THE
Telcon Works, Manor Royal, Crawley, Sussex
tel: 1560
TELEHOIST LTD
Cheltenham, Glos tel: 53254
TELEKTRON (GB) LTD
109 Jermyn St, London, SW1 tel: Trafalgar 1901
TELEMETERS LTD
119 Victoria St, London, SW1 tel: Victoria 2670
TELEPHONE MFG CO LTD
Hollingsworth Works, London, SE21
tel: Gipsy Hill 2211
TELEPHONE RENTALS LTD
60 Kent House, Rutland Gardens, Knightsbridge, London, SW7 tel: Kensington 9201
TELEVOX (LONDON) LTD
5 Bourne St, Sloane Sq, London, SW1
tel: Sloane 3583
TELLUX LTD
146 New Cavendish St, London, W1
tel: Langham 2411
TESTGEAR COMPONENTS (LONDON) LTD
173–177 High St, Orpington, Kent tel: 23285
TEST EQUIPMENT LTD
Gatwick Rd, Crawley, Sussex tel: 2350
TEXAS INSTRUMENTS LTD
Dallas Rd, Bedford tel: 68051
THERMAL CONTROL CO LTD
Marine Works, Sackville Rd, Hove, Sussex
tel: 35929
THERMAL SYNDICATE LTD, THE
PO Box No. 6, Wallsend, Northumberland
tel: 6342
THERMIONIC PRODUCTS LTD
Hythe, Southampton tel: Hythe 3265
THERMOCONTROL INSTALLATIONS CO LTD
2–10 Valentine Place, Blackfriars Rd, London, SE1 tel: Waterloo 7356

THERMOSTATIC CONTROLS CO, THE
Avenue Rd, Hampton, Middx tel: Molesey 3285
THOMPSON, DIAMOND & BUTCHER LTD
5 University St, London, WC1 tel: Euston 3494
THOMPSON INSTRUMENT CO LTD, JOHN
Ettingshall, Wolverhampton tel: Bilston 41121
THOMPSON LTD, J LANGHAM
88 High Rd, Bushey Heath, Herts
tel: Bushey 2411
THOMPSON-KENNICOTT LTD, JOHN
Ettingshall, Wolverhampton tel: Bilston 41121
THOMSON & SONS (LIVERPOOL) LTD, S
Gladstone Works, Fort Rd, Liverpool, 21
tel: Bootle 2697
THORNBER & SONS, J. E
Globe Works, Cornbrook St, Manchester, 16
tel: Moss Side 3537
TILGHMAN'S LTD
Broadheath, Altrincham, Ches tel: 4242
TINSLEY & CO LTD, H
Werndee Hall, London, SE25
tel: Addiscombe 6046
TINTOMETER CO LTD, THE
Waterloo Rd, Salisbury, Wilts tel: 2837
TORMO LTD
Endersleigh Gardens, Watford Way, London, NW4
tel: Hendon 7446
TOWERS & CO LTD, J. W
Victoria Ho, Widnes, Lancs tel: 2201
TOWLER BROS (PATENTS) LTD
Electraulic Works, Rodley, Leeds
tel: Pudsey 3125
TOWNSON & MERCER LTD
Beddington Lane, Croydon, Surrey
tel: Thornton Heath 6262
TRANSMISSION ACCESSORIES LTD
Leighton Buzzard, Beds tel: 2441
TRIPLETONE MFG CO, THE
147 Merton Rd, London, SW19 tel: Liberty 6525
TRIST & CO LTD, RONALD
Bath Rd, Slough, Bucks tel: 25041
TRIX ELECTRICAL CO LTD, THE
1–5 Maple Place, Tottenham Court Rd, London, W1 tel: Museum 5817
TRUCHORD LTD
82 Gt Portland St, London, W1 tel: Museum 7674
TRUMETER CO LTD
Milltown St, Radcliffe, Lancs tel: 2675
TRUVOX LTD
Truvox Ho, 15 Lyon Rd, Harrow, Middx
tel: Harrow 9282
TUBES LTD
Rocky Lane, Birmingham, 6
tel: Aston Cross 3030
TUDOR ACCUMULATOR CO LTD, THE
137 Victoria St, London, SW1
tel: Tate Gallery 0307
TUFNOL LTD
Perry Barr, Birmingham, 22B tel: Birchfields 4554
TUNGSTONE PRODUCTS LTD
10 Salisbury Sq, London, EC4
tel: Fleet Street 8011
TURNER ELECTRICAL INSTRUMENTS LTD, ERNEST
Chiltern Works, High Wycombe, Bucks tel: 1301
TURNER (KISMET) LTD, WILLIAM
Eyre Works, Sheffield tel: 20333
20TH CENTURY ELECTRONICS LTD
King Henry's Drive, New Addington, Croydon, Surrey tel: Lodge Hill 2121
TYLORS OF LONDON LTD
Bright Works, Burgess Hill, Sussex tel: 263
ULTRA ELECTRIC LTD
Western Av, Acton, London, W3 tel: Acorn 3434
ULTRASONICS LTD
Westgate, Otley, Yorks tel: 3221
ULTRASONOSCOPE CO (LONDON) LTD
47c Sudbourne Rd, London, SW2
tel: Brixton 4041
UNICAM INSTRUMENTS LTD
Arbury Works, Cambridge tel: 55227
UNITELEX (LONDON) LTD
2 Pagnell St, London, SE14 tel: Tideway 5842
UNITY HEATING LTD
Chilworth Manor, Southampton tel: 68844
UNITED KINGDOM OPTICAL CO LTD
Mill Hill, London, NW7 tel: Finchley 2660
UNIVERSAL BALL BEARING REPAIR & MANUFACTURING CO
111–115 Hammersmith Grove, London, W6
tel: Riverside 3262
UNIVERSAL CONTROL EQUIPMENT LTD
Queens Chambers, 61 Boldmere Rd, Sutton Coldfield, Warws tel: 5258
VACTRIC (CONTROL) LTD
196 Sloane St, London, SW1 tel: Sloane 9656
VACUUM INDUSTRIAL APPLICATIONS LTD
Wishaw, Lanarks tel: Wishaw 142
VARILECTRIC LTD
10 Melon Rd, London, SE15 tel: Rodney 6895
VARLEY DRY ACCUMULATORS LTD
By-Pass Rd, Barking, Essex tel: Rippleway 3346
VARLEY-FMC LTD
Ferry Lane, Brentford, Middx tel: Ealing 1185
VAUGHAN & CO LTD, EDGAR
Legge St, Birmingham, 4 tel: Aston Cross 2071
VEEDER-ROOT LTD
20 Kilspindie Road, Dundee tel: 85218
VENNER ACCUMULATORS LTD
(See Venner Ltd)
VENNER ELECTRONICS LTD
(See Venner Ltd)
VENNER LTD
Kingston By-Pass, New Malden, Surrey
tel: Malden 2442
VERDIK SALES LTD
8 Rupert Court, Wardour St, London, W1
tel: Gerrard 8266
VERITYS LTD
Brettenham Ho, Lancaster Place, London, WC2
tel: Temple Bar 3835

VERNONS INDUSTRIES LTD
Kirkby Industrial Estate, Liverpool
tel: Simonswood 3261

VERNON INSTRUMENT CO LTD
Wilbury Way, Hitchin, Herts tel: 2523

VICKERS-ARMSTRONGS (ENGINEERS) LTD
Vickers Ho, Broadway, London, SW1
tel: Abbey 7777

VICSONS LTD
148 Pinner Rd, Harrow, Middx tel: Harrow 0706

VICTORIA INSTRUMENTS LTD
Midland Terrace, Victoria Rd, London, NW10
tel: Elgar 7871

VIDOR LTD
West St, Erith, Kent tel: 3080

VLASTO, CLARK & WATSON LTD
London Road Bridge, Stockton Heath, Warrington
tel: Stockton Heath 17

VOKES LTD
Guildford, Surrey tel: 62861

VOLSPRAY LTD
Grosvenor Gardens Ho, Grosvenor Gardens, London, SW1 tel: Tate Gallery 7070

VORTEXION LTD
257–263 The Broadway, London, SW19
tel: Liberty 2814

WADE COUPLINGS LTD
39–47 East Rd, London, N1
tel: Clerkenwell 2534

WAKEFIELD & CO LTD, C. C
46 Grosvenor St, London, W1 tel: Mayfair 9232

WALKER BROS (WIGAN) LTD
Pagefield Ironworks, Wigan tel: 14

WALKER, CROSSWELLER & CO LTD
Cheltenham, Glos tel: 56317

WALKER & SON LTD, THOMAS
58 Oxford St, Birmingham, 5 tel: Midland 5474

WALTER INSTRUMENTS LTD
Garth Rd, Morden, Surrey tel: Derwent 4421

WALTER'S ELECTRICAL MFG CO LTD
Kensaltown Works, Kensal Rd, London, W10
tel: Ladbroke 2323

WARDEN & CO LTD
44–48 Shepherdess Walk, City Rd, London, N1
tel: Clerkenwell 3616

WATFORD ELECTRIC & MFG CO LTD
Whippendell Rd, Watford, Herts tel: 4218

WATSON, MANESTY & CO LTD
139 Richmond Rd, Kingston-on-Thames, Surrey
tel: Kingston 7008

WATSON & SMITH LTD, JOHN
26 Albion Pl, Leeds, 1 tel: 20765

WATSON & SONS LTD, W
313 High Holborn, London, WC1
tel: Holborn 2767

WAYMOUTH GAUGES & INSTRUMENTS LTD
Station Rd, Godalming, Surrey tel: 1330

WAYNE KERR LABORATORIES LTD, THE
Roebuck Rd, Chessington, Surrey
tel: Lower Hook 1131

WELWYN ELECTRICAL LABORATORIES LTD
Bedlington Station, Northumberland
tel: Bedlington 2181

WEBB LTD, WILLIAM A
1–9 Perrymans Farm Rd, Newbury Park, Ilford, Essex tel: Valentine 6370

WEIR LTD, G. & J
Holm Foundry, Cathcart, Glasgow, S4
tel: Merrylee 7141

WELMEC CORPORATION LTD
147 Strand, London, WC2 tel: Temple Bar 3357

WEST INSTRUMENT LTD
52 Regent St, Brighton, Sussex tel: 28106

WESTERN DETAIL MFRS LTD
Western Works, Staple Hill, Bristol tel: 655097

WESTERN MFG (READING) LTD
The Aerodrome, Reading tel: Sonning 2351

WESTINGHOUSE BRAKE & SIGNAL CO LTD
82 York Way, London, N1 tel: Terminus 6432

WESTON WORKS (BIRMINGHAM) LTD
Weston Lane, Birmingham, 11
tel: Acocks Green 3936

WESTOOL LTD
St Helens, Bishop Auckland, Co Durham
tel: West Auckland 317

WESTOVER HYDRAULICS
Fluid Works, River Rd, Barking, Essex
tel: Rippleway 2217

WESTREX CO LTD
Liberty Ho, Regent St, London, W1
tel: Regent 1001

WEYCO (EQUIPMENT) LTD
18–20 Dames Rd, London, E7 tel: Maryland 4334

WEYERS BROS LTD
Langston Rd, Loughton, Essex
tel: Loughton 3886

WHITE ELECTRICAL INSTRUMENT CO LTD
10 Amwell St, Rosebery Avenue, London, EC1
tel: Terminus 2471

WHITELEY ELECTRICAL RADIO CO LTD
Portland Mills, Victoria St, Mansfield, Notts
tel: Mansfield 1762

WHITETRADE LTD
70 Maidstone Rd, Rochester, Kent
tel: Chatham 4638

WHITTAKER, HALL & CO (1929) LTD
Black Lane Engineering Works, Radcliffe, Manchester tel: Radcliffe 2421

WICKMAN LTD
Banner Lane, Tile Hill, Coventry tel: 66271

WILDBORE LTD, J. E
6–12 Peter St, Oldham, Lancs tel: Main 4475

WILKINSON RUBBER LINATEX LTD
Camberley, Surrey tel: 1595

WILLIAMS & JAMES (ENGINEERS) LTD
Chequers Bridge, Gloucester tel: 24021

WILLIAMS (BIRMINGHAM) LTD, R. A
Stereo Works, Huslucks Green Rd, Shirley, Birmingham tel: Shirley 2591

WILSON & PARTNERS LTD, A. C
Design Ho, The Mall, Ealing, W5 tel: Ealing 9843

WINSTON ELECTRONICS LTD
Govett Avenue, Shepperton, Middx
tel: Walton-on-Thames 6321

WITTON-JAMES LTD
Hyde Electrical Works, Edgware Rd, London, NW9 tel: Colindale 6192

WITTON-KRAMER ELECTRICAL TOOL & HOIST WORKS
Witton, Birmingham, 6 tel: East 1941

WODEN TRANSFORMER CO LTD
Moxley Rd, Bilston, Staffs tel: Bilston 41959

WOLF SAFETY LAMP CO LTD
Saxon Rd Works, Sheffield, 8 tel: Sheffield 51051

WORCESTER ROYAL PORCELAIN CO LTD
Worcester tel: 3221

WORTHINGTON-SIMPSON LTD
Newark-on-Trent, Notts tel: Newark 601

WRAY (OPTICAL WORKS) LTD
Ashgrove Rd, Bromley, Kent
tel: Ravensbourne 1729

WRIGHT & WEAIRE LTD
Simonside Works, South Shields, Co Durham
tel: 2301

WS ELECTRONICS (PRODUCTION) LTD
Brunel Rd, Acton, W3 tel: Shepherds Bush 7601

WYKEHAM & CO LTD, W
17–19 Cockspur St, London, SW1
tel: Whitehall 5307

WYNN & CO (AIRCRAFT) LTD, E. D
Staverton Aerodrome, Gloucester
tel: Churchdown 3264

X-LON PRODUCTS LTD
48 Gillingham St, London, SW1 tel: Victoria 7412

YOUNGS (LIFTING APPLIANCES) LTD
Ryland Street Works, Birmingham, 16
tel: Edgbaston 3508

ZEAL LTD, G. H
Lombard Rd, Morden Rd, London, SW19
tel: Liberty 2283

BUYERS' GUIDE

Absorptiometers
★ Circle *No 1* on reply card
Atkins, Robertson & Whiteford Ltd
Baird & Tatlock (London) Ltd
Evans Electroselenium Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Hilger & Watts Ltd
Infra-Red Development Co Ltd
Joyce, Loebl & Co Ltd
J. V. Radio & Television Ltd
Lock & Co Ltd, A. M
Nash & Thompson Ltd
Optical Works Ltd
Townson & Mercer Ltd
Unicam Instruments Ltd

Accelerometers
★ Circle *No 2* on reply card
Aveley Electric Ltd
Barr & Stroud Ltd
B. & K. Laboratories Ltd
Cambridge Instrument Co Ltd
Cawkell Research & Electronics Ltd
Dawe Instruments Ltd
Dobbie McInnes Ltd
Elliott Bros (London) Ltd
Electro Mechanisms Ltd
EMI Electronics Ltd
Fairey Aviation Co Ltd, The
Films & Equipment Ltd
General Electric Co Ltd, The
Graseby Instruments Ltd
Hendry Relays Ltd
Kelvin & Hughes Ltd
Lintronic Ltd
McKellen Automation Ltd
Mechanical & Electronic Products (London) Ltd
Mechanism Ltd
Nash & Thompson Ltd
New Electronic Products Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Saunders-Roe Ltd
Smiths Aircraft Instruments Ltd
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
Technical Ceramics Ltd
Teddington Aircraft Controls Ltd
Test Equipment Ltd
Thompson Ltd, J. Langham

Actuators—electric
★ Circle *No 3* on reply card
Allied Electronics Ltd
Air Trainers Link Ltd
Airtech Ltd
B. & K. Laboratories Ltd
Bell Precision Engineering Co Ltd
British Thomson-Houston Co Ltd, The
Brown Ltd, S. G
Chamberlain Industries Ltd
Dowty Nucleonics Ltd
Electro-Hydraulics Ltd
Electronic Machine Co Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Gloster Aircraft Co Ltd
Goodmans Industries Ltd
Hobson Ltd, H. M
Hydraulics & Pneumatics Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Magnetic Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Pell Control Ltd, Oliver
Phillips Control (G.B.) Ltd
Plessey Co Ltd, The
Sauter Controls Ltd
Sperry Gyroscope Co Ltd
Teddington Industrial Equipment Ltd
Teleflex Products Ltd
Thermocontrol Installations Co Ltd
Vernons Industries Ltd
Watford Electric & Mfg Co Ltd
Western Mfg (Reading) Ltd
Weyers Bros Ltd

Actuators—hydraulic (cylinders)
★ Circle *No 4* on reply card
Airtech Ltd
Automotive Products Co Ltd (Lockheed Industrial Hydraulics Division)
Baldwin Instrument Co Ltd
Bell Precision Engineering Co Ltd
Black Automatic Control Ltd
British Messier Ltd
Cattermole and Co (Hydraulics) Ltd, H. S
Chamberlain Industries Ltd
Dowty Hydraulic Units Ltd
Exactor Ltd
Gloster Aircraft Co Ltd
Graseby Instruments Ltd
Hobson Ltd, H. M
Hydraulics & Pneumatics Ltd
Integral Ltd
Keelavite Rotary Pumps and Motors Ltd
Leeds Engineering and Hydraulic Co Ltd
Martonair Ltd
Oswalds and Ridgway Ltd
Plessey Co Ltd, The
Power Jacks Ltd
Solartron Electronic Group Ltd, The
Spenborough Engineering Co Ltd
Sperry Gyroscope Co Ltd
Stein Atkinson Vickers Hydraulic Ltd
Tangye Ltd
Teleboist Ltd
Weston Works (B'ham) Ltd
Westover Hydraulics

Actuators—pneumatic (cylinders)
★ Circle *No 5* on reply card
Airtech Ltd
Baldwin Instrument Co Ltd
Black Automatic Controls Ltd
Climax Rock Drill and Engineering Works Ltd
Consolidated Pneumatic Tool Co Ltd
Crosby Valve & Engineering Co Ltd
Globe Pneumatic Engineering Co Ltd
Gloster Aircraft Co Ltd
Hydraulics and Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Kent Ltd, George
Lang Pneumatic Ltd
Martonair Ltd
Marley and Co Ltd, W. M
Mills and Co Ltd, John
Pneuspeed Ltd
Sauter Controls Ltd
Schrader's Son, A
Telektron (G.B.) Ltd

Air compressors
★ Circle *No 6* on reply card
Air Pumps Ltd
Alley & MacLellan (Polmadie) Ltd
Apparatus & Instruments Co Ltd
Barnet Instruments Ltd
Bellis & Morcom Ltd
British Thomson-Houston Co Ltd, The
Broom & Wade Ltd
Brotherhood Ltd, Peter
Bullows & Sons Ltd, Alfred
English Electric Co Ltd, The
Farrow & Sons Ltd
Foxboro-Yoxall Ltd

★ *For further details circle on card facing page A60*

General Electric Co Ltd, The
Gloster Aircraft Co Ltd
Hamworthy Engineering Co Ltd
HEC Compressors & Engines Ltd
Holman Bros Ltd
Hymatic Engineering Co Ltd
Keith Blackman Ltd
Lacy-Hulbert & Co Ltd
Laycock Engineering Ltd
Levis Ltd
Metropolitan-Vickers Electrical Co Ltd
Northey Rotary Compressors Ltd
Parsons & Co Ltd, C. A
Reavell & Co Ltd
Richardsons, Westgarth (Hartlepool) Ltd
Taylor Controls Ltd
Tecalemit Ltd
Weir Ltd, G. & J
Williams & James (Engineers) Ltd

Aircraft instruments

★ Circle *No 7* on reply card

Aveley Electric Ltd
Airflow Developments Ltd
Avimo Ltd
Appleby & Ireland Ltd
B & K Laboratories Ltd
British Rototherm Co Ltd, The
Budenberg Gauge Co Ltd
Cambridge Instrument Co Ltd
Cass & Phillip Ltd
Counting Instruments Ltd
Darton & Co Ltd, F
Devon Instruments Ltd
Electro Mechanisms Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Evershed & Vignoles Ltd
Ferranti Ltd
Firth Cleveland Instruments Ltd
Foundrometers Ltd
General Electric Co Ltd, The
Glass Developments Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Graseby Instruments Ltd
Honeywell Controls Ltd
Hobson Ltd, H. M
Hydraulic Recording Instruments Ltd
Kandem Electrical Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Liquid Systems Ltd
Liquids Control Ltd
Mechanism Ltd
Negretti & Zambra Ltd
Normalair Ltd
Parkinson & Cowan Instruments
Pullin & Co Ltd, R. B
Pye & Co Ltd, W. G
Reid & Sigrist Ltd
Rollason Aerocessories Ltd
Salford Electrical Instruments Ltd
Sangamo Weston Ltd
Saunders-Roe Ltd
SFIM (Great Britain) Ltd
Shackman & Sons, D
Smiths Aircraft Instruments Ltd
Sperry Gyroscope Co Ltd
Standard Telephones & Cables Ltd
Stanley & Co Ltd, W. F
Sterling Instrument Co Ltd
Short Bros & Harland Ltd
Thompson Ltd, J. Langham
Turner Electrical Instruments Ltd, Ernest
Teddington Aircraft Controls Ltd
Test Equipment Ltd
Waymouth Gauges & Instruments Ltd
Wynn & Co (Aircraft) Ltd, E. D

Alarms—miscellaneous

★ Circle *No 8* on reply card

Cambridge Instrument Co Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
General Electric Co Ltd, The
Klaxon Ltd
Londex Ltd
Rank Cintel Ltd
WS Electronics (Production) Ltd

Alarms—radiation

★ Circle *No 9* on reply card

British Thomson-Houston Co Ltd, The
Dowty Nucleonics Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
General Electric Co. Ltd, The
General Radiological Ltd
Glass Developments Ltd
Isotope Developments Ltd
Labgear Ltd
Lock & Co Ltd, A. M
Panax Equipment Ltd
Plessey Nucleonics Ltd
Research & Control Instruments Ltd
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd

Alarms—smoke

★ Circle *No 10* on reply card

Airmec Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
British Thomson-Houston Co Ltd, The
Electro-Magnetic Control Co
Foster Instrument Co Ltd
General Electric Co Ltd, The
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Kingston Control Systems Ltd
Lock & Co Ltd, A. M
Londex Ltd
Lancashire Dynamo Electronic Products Ltd
Minerva Detector Co Ltd
Radiovisor Parent Ltd
Shandon Scientific Co Ltd
Trist & Co Ltd, Ronald

Alarms—temperature

★ Circle *No 11* on reply card

Accurate Recording Instrument Co, The
Allied Electronics Ltd
Appleby & Ireland Ltd
British Thomson-Houston Co Ltd, The
Bailey Meters & Controls Ltd
Cambridge Instrument Co Ltd
Elcontrol Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
General Electric Co Ltd, The
Gordon & Co Ltd, James
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
KDG Instruments Ltd
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Lock & Co Ltd, A. M
Londex Ltd
McKellen Automation Ltd
Negretti & Zambra Ltd
Research & Control Instruments Ltd
Short & Mason Ltd
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd
Teddington Industrial Equipment Ltd
Universal Control Equipment Ltd
Watford Electric & Mfg Co Ltd

Alarms—liquid level

★ Circle *No 12* on reply card

Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Danfoss Mfg Co
Elcontrol Ltd
Electro-Magnetic Control Co
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Gordon & Co Ltd, James
Hopkinsons Ltd
KDG Instruments Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lock & Co Ltd, A. M
Londex Ltd
Lancashire Dynamo Electronic Products Ltd
Magnetic Controls Ltd
Negretti & Zambra Ltd
Sunvic Controls Ltd
Teddington Industrial Equipment Ltd
Watford Electric & Mfg Co Ltd

Amplifiers—a.f

★ Circle *No 13* on reply card

Allied Electronics Ltd
Amos (Electronics) Ltd
Andec Ltd
Associated Electronic Engineers Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
Cass & Phillip Ltd
Cawkell Research & Electronics Ltd
Craven Electronics Ltd
Dowty Equipment Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Furzehill Laboratories Ltd
General Electric Co Ltd, The
Goodmans Industries Ltd
Griffin & George Ltd
Hifi Ltd
Instruments & Controls Ltd
Kandem Electrical Ltd
Kendall & Mousley Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Lion Electronic Developments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
MSS Recording Co Ltd
PAR Ltd
Parmeko Ltd
Phillips & Bronson Ltd
Pullin & Co. Ltd, R. B
Racal Engineering Ltd
Redifon Ltd
Reosound Engineering & Electrical Co
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Savage Ltd, W. Bryan
SS Electronics Ltd
Shipton & Co Ltd, E
Smurthwaite Electronics
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Sullivan Ltd, H. W
Trix Electrical Co Ltd
Walter Instruments Ltd

Amplifiers—d.c

★ Circle *No 14* on reply card

Addison Electric Co Ltd
Allied Electronics Ltd
Air Trainers Link Ltd
Airmec Ltd
Airtech Ltd
Amos (Electronics) Ltd
Andec Ltd
Amplivox Ltd
Appleby & Ireland Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Belling & Lee Ltd
Boulton Paul Aircraft Ltd
British Physical Laboratories
British Thomson-Houston Co Ltd, The
Burndept Ltd
Cossor Instruments Ltd
Cawkell Research & Electronics Ltd
Craven Electronics Ltd
Dowty Nucleonics Ltd
Dulci Co Ltd, The
Dynatron Radio Ltd
Easco Electrical (Holdings) Ltd
Ekco Electronics Ltd
Elcontrol Ltd
Electro Mechanisms Ltd
Electro Methods Ltd
Electronic Instruments Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
English Electric Valve Co Ltd
Ericsson Telephones Ltd
Evershed & Vignoles Ltd
Falk & Co Ltd, M
Faraday Electronic Instruments Ltd
Ferranti Ltd
Fielden Electronics Ltd
Fleming Radio (Developments) Ltd
Foster Instruments Ltd
General Electric Co Ltd, The
General Radiological Ltd
Goodmans Industries Ltd
Graseby Instruments Ltd
Hifi Ltd
Hirst Electronic Ltd
Honeywell Controls Ltd
Hilger & Watts Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
Kendall & Mousley Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Ketay Ltd
Labgear Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence Scott & Electromotors Ltd
Livingston Laboratories Ltd
McKellen Automation Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Nash & Thompson Ltd
Nagard Ltd
New Electronic Products Ltd
Panax Equipment Ltd
Parmeko Ltd
Phillips & Bonson Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Pye & Co Ltd, W. G
Radiovisor Parent Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Salford Electrical Instruments Ltd
Sangamo Weston Ltd
Sanders (Electronics) Ltd, W. H
Savage Ltd, W. Bryan
Savage & Parsons Ltd
Servomex Controls Ltd
Short Bros & Harland Ltd
Sierex Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
SS Electronics Ltd

Saunders-Roe Ltd
Sullivan Ltd, H. W
Sunvic Controls Ltd
Teledictor Ltd
Thompson Ltd, J. Langham
Tinsley & Co Ltd, H.
Tripletone Mfg Co Ltd
Venner Electronics Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Amplifiers—hydraulic
★ Circle No 15 on reply card
Elliott Bros (London) Ltd
Fairey Aviation Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Solartron Electronic Group Ltd, The

Amplifiers—magnetic
★ Circle No 16 on reply card
Addison Electric Co Ltd
Amos (Electronics) Ltd
Andec Ltd
Appleby & Ireland Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
British Thomson-Houston Co Ltd, The
Broadcast & Acoustic Equipment Co Ltd
CJR Electrical & Electronic Developments Ltd
Corex Communications Equipment (1948) Ltd
De Havilland Propellors Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Express Winding Co
Fortiphone Ltd
Foster Transformers Ltd
GB-Kalee Ltd
General Electric Co Ltd, The
Gresham Transformers Ltd
Gloster Aircraft Co Ltd
Haddon Transformers Ltd
Hatfield Instruments Ltd
Hirst Electronic Ltd
Holgate of Totton Ltd
Hymatic Engineering Co Ltd, The
Igranic Electric Co Ltd
JD Electronics Ltd
Kershaw & Sons Ltd, A
Ketay Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Lee Products (GB) Ltd
Lion Electronic Developments Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Morris Electrical Engineering Co Ltd, John
PAR Ltd
Parmeko Ltd
Plessey Developments Co Ltd
Pullin & Co Ltd, R. B
Pye & Co Ltd, W. G
Racal Engineering Ltd
Rivlin Instruments Ltd
Sanders (Electronics) Ltd, W. H
Servomex Controls Ltd
Sperry Gyroscope Co Ltd
Stonebridge Electrical Co Ltd, The
Tannoy Products Ltd
Teddington Aircraft Controls Ltd
Telefusion (Engineering) Ltd
Tellux Ltd
Testgear Components (London) Ltd
Ultra Electric Ltd
Vernons Industries Ltd
Welmec Corporation Ltd
Westool Ltd
West Instruments Ltd
Winston Electronics Ltd

Amplifiers—miscellaneous
★ Circle No 17 on reply card
Amplivox Ltd
Appleby & Ireland Ltd
Aveley Electric Ltd
Barr & Stroud Ltd
British Physical Laboratories
Cawkell Research & Electronics Ltd
Cossor Instruments Ltd
Craven Electronics Ltd
Dynatron Radio Ltd
Ericsson Telephones Ltd
General Electric Co Ltd, The
Joyce, Loebel & Co Ltd
Kelvin & Hughes Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Microwave Instruments Ltd
Pye & Co. Ltd, W. G
Rank Cintel Ltd
Sperry Gyroscope Co Ltd
Solartron Electronic Group Ltd, The
Sunvic Controls Ltd

Amplifiers—pneumatic
★ Circle No 18 on reply card
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Electro Methods Ltd
Gordon & Co Ltd, James
Hymatic Engineering Co Ltd, The
Kent Ltd, George
Negretti & Zambra Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Telektron Ltd
Teddington Aircraft Controls Ltd

Amplifiers—r.f
★ Circle No 19 on reply card
Allied Electronics Ltd
Amos (Electronics) Ltd
Andec Ltd
Avo Ltd
Aveley Electric Ltd
Cawkell Research & Electronics Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
EMI Electronics Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
General Radiological Ltd
Hifi Ltd
Kandem Electrical Ltd
Kent Ltd, George
Leland Instruments Ltd
Livingston Laboratories Ltd
Lancashire Dynamo Electronic Products Ltd
Nagard Ltd
PAR Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Racal Engineering Ltd
Robinson & Partners Ltd, F. C
Smurthwaite Electronics
Solartron Electronic Group Ltd, The
SS Electronics Ltd
Standard Telephones & Cables Ltd
Sullivan Ltd, H. W

Amplifiers—rotating machine
★ Circle No 20 on reply card
British Thompson-Houston Co Ltd, The
English Electric Co Ltd, The
Macfarlane Engineering Co Ltd
Metropolitan-Vickers Electrical Co Ltd, The
Vernons Industries Ltd

Annunciators
★ Circle No 21 on reply card
Chamberlain Industries Ltd
Magnetic Controls Ltd
Panellit Ltd
Standard Telephones & Cables Ltd
Sunvic Controls Ltd
WS Electronics (Production) Ltd

Anti-vibration apparatus
★ Circle No 22 on reply card
AVA Ltd
Baird & Tatlock Ltd
BTR Industries Ltd
Cambridge Instrument Co Ltd
Cementation (Muffelite) Ltd
Clayton-Wright Ltd, Howard
Cooper & Co (Birmingham) Ltd
Cork Mfg Co Ltd
Dunlop Special Products Ltd
Expanded Rubber Co Ltd
Fenner & Co Ltd, J. H
Griffin & George Ltd
Knitted Mesh Mfg Co Ltd
Metalastik Ltd (Mountings)
Mitchell & Snow Ltd, N. W
Rubber Bonders Ltd
Silentbloc Ltd
Smiths Aircraft Instruments Ltd
Towers & Co Ltd, J. W
Wildbore Ltd, J. E.
Wilkinson Rubber Linatex Ltd

Balances—analytical
★ Circle No 23 on reply card
Avery Ltd, W. & T
Baird & Tatlock (London) Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Nicolson (Scientific Instruments) Ltd, W. B
Oertling Ltd, L
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balances—micro-chemical
★ Circle No 24 on reply card
Baird & Tatlock (London) Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Oertling Ltd, L
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balances—automatic weighing
★ Circle No 25 on reply card
Avery Ltd, W. & T
B & K Laboratories Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Nash & Thompson Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Western Mfg (Reading) Ltd

Balances—weight (precision)
★ Circle No 26 on reply card
Avery Ltd, W. & T
Baird & Tatlock (London) Ltd
Cuthbert Ltd, Ralph
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Hilger & Watts Ltd
Nash & Thompson Ltd
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balances—aperiodic
★ Circle No 27 on reply card
Avery Ltd, W. & T
Baird & Tatlock (London) Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Oertling Ltd, L
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balancing machines—dynamic
★ Circle No 28 on reply card
Avery Ltd, W. & T
British Thomson-Houston Co Ltd, The
Burton, Griffiths & Co Ltd
Dawe Instruments Ltd
EMI Ltd
EMI Electronics Ltd
Farnell Instruments Ltd
Geisler Ltd, C. F. R
Griffin & George Ltd
Herbert Ltd, Alfred
Herbert Ltd, Edward G
Jackson & Bradwell Ltd
Livingston Laboratories Ltd
Lock Ltd, A. M
LMK Mfg Co Ltd
Pullin & Co Ltd, R. B
Reid & Sigrist Ltd
Robinson & Partners Ltd, F. C
Samwell & Hutton Ltd
Small Electric Motors Ltd
Solartron Electronic Group Ltd, The
Test Equipment Ltd
Western Mfg (Reading) Ltd
Weyco Equipment Ltd
Wickman Ltd

Balancing machines—static
★ Circle No 29 on reply card
Avery Ltd, W. & T
Burton, Griffiths & Co Ltd
Reid & Sigrist Ltd
Wickman Ltd

Ball bearings—miniature
★ Circle No 30 on reply card
BMB (Sales) Ltd
British Timken Ltd
Dick Ltd, R. & J
EMO Instrumentation Ltd (Precision)
Fischer Bearings Co Ltd
Gurney & New Ltd
Hallmac Tools Ltd
Hoffman Mfg Co Ltd
International Engineering Concessionaires Ltd
London V-Rope Drive Co
Melvin Bros Ltd
Miniature Bearings Ltd
Quality Bearings Ltd
Ransome & Marles Bearing Co Ltd
Reid & Sigrist Ltd
Rye Bearings, Claude
Skefco Ball Bearing Co Ltd
Smith & Grace Ltd
Spiro Ball Bearing Co Ltd
Tormo Ltd
Townson & Mercer Ltd
Universal Ball Bearing Repair & Mfg Co Ltd
Warden & Co Ltd, A

Batteries—dry
★ Circle No 31 on reply card
Alpha Accessories Ltd
Atlas Carbon & Battery Co Ltd
Burndept Ltd
Chloride Batteries Ltd
EMI Ltd
Ever Ready Co (Gt Britain) Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Le Carbone (Gt Britain) Ltd
Livingston Laboratories Ltd
Mallory Batteries Ltd
Oldham & Son Ltd
Siemens Edison Swan Ltd
Silvertown Rubber Co Ltd

Sterdy Telephones Ltd
Vidor Ltd
Varley Dry Accumulators Ltd

Batteries—mercury
★ Circle *No 32* on reply card
Burndept Ltd
Mallory Batteries Ltd
Vidor Ltd

Batteries—solar
★ Circle *No 33* on reply card
B & K Laboratories Ltd
Livingston Laboratories Ltd

Batteries—storage
★ Circle *No 34* on reply card
Alton Battery Co Ltd, The
Britannia Batteries Ltd
British Electrical & Mfg Co Ltd
Brooke Industries Ltd
CAV Ltd
Chloride Batteries Ltd
Christie & Sadler Ltd
Crompton Parkinson Ltd
Diamex Ltd
DP Battery Co Ltd, The
Dunlop (Battery) Co Ltd
Gnu Accumulator Co Ltd
Lucas Ltd, Joseph
Mine & Safety Appliances Co Ltd
Nife Batteries
Oldham & Son Ltd
Palmer Ltd, G. A. Stanley
Peto & Radford Ltd
Pritchett & Gold & EPS Co Ltd
Radenite Batteries Ltd
Siemens Edison Swan Ltd
Tudor Accumulator Co Ltd
Tungstone Products Ltd
Varley Dry Accumulators Ltd
Venner Accumulators Ltd

Bellows—metallic
★ Circle *No 35* on reply card
Appleby & Ireland Ltd
Avica Equipment Ltd
Drayton Regulator & Instrument Co Ltd
Griffin & George Ltd
Leybold Vacuum Sales Ltd
Palatine Tool & Engineering Co (Surbiton) Ltd
Power Flexible Tubing Co Ltd, The
Samson Controls (London) Ltd
Teddington Aircraft Controls Ltd

Bellows—non-metallic
★ Circle *No 36* on reply card
Appleby & Ireland Ltd
Beakbane (Fortox) Ltd, Henry
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Helvetia Leather Co Ltd
Hall & Hall Ltd
Townson & Mercer Ltd

Boiler controls & instrumentation
★ Circle *No 37* on reply card
Accurate Recording Instrument Co Ltd
Airflow Developments Ltd
Appleby & Ireland Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
Black Automatic Controls Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Cass & Phillip Ltd
Colostat Combustion Systems Ltd
Combustion Equipment Ltd
DEV Engineering Co Ltd
Danfoss Mfg Co
De La Rue & Co Ltd, Thomas (Potterton Division)
Elcontrol Ltd
Electroflo Meters Co Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Ether Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Fireye Controls Ltd
Foxboro-Yoxall Ltd
Foster Instrument Co Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Ionic Instruments (London) Ltd
JV Radio & Television Ltd
Kandem Electrical Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Metropolitan Engineering Co Ltd
Metropolitan-Vickers Electrical Co Ltd
Nalder Bros & Thompson Ltd
Nash & Thompson Ltd
Parkinson & Cowan Instruments
Perl Controls Ltd
Pye & Co Ltd, W. G
Radiovisor Parent Ltd
Reavell & Co
Rheostatic Co Ltd,, The
Samson Controls (London) Ltd
Sauter Controls Ltd
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Teleflex Products Ltd
Thermocontrol Installations Co Ltd
Thompson Instruments Co Ltd, John
Trist & Co Ltd, Ronald
Tylors of London Ltd
Wykeham & Co Ltd, W

Bolometers
★ Circle *No 38* on reply card
Aveley Electric Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Livingston Laboratories Ltd
Standard Telephones & Cables Ltd

Bourdon—tubes
★ Circle *No 39* on reply card
Accles & Pollock Ltd
Appleby & Ireland Ltd
Booth & Co Ltd, James
Cambridge Instrument Co Ltd
Crosby Valve & Engineering Co Ltd
Johnson, Matthey & Co Ltd
KDG Instruments Ltd
Teddington Aircraft Controls Ltd

Bridges—a.c
★ Circle *No 40* on reply card
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Croydon Precision Instrument Co
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Lintronic Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Microcell Electronics
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
New Electronic Products Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Wayne Kerr Laboratories Ltd
Welmec Corporation Ltd
Wykeham & Co Ltd, W

Bridges—capacitance
★ Circle *No 41* on reply card
Allied Electronics Ltd
Amos (Electronics) Ltd
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
B & K Laboratories Ltd
BPL (Instruments) Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Clare Instrument Co Ltd
Copper & Alloys Ltd
Croydon Precision Instrument Co
Dawe Instruments Ltd
Doran Instrument Co Ltd
Electrical Instrument Co (Hillington) Ltd, The
Emeco Electronics Ltd
EMI Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Furzehill Laboratories Ltd
Fielden Electronics Ltd
Gambrell Bros & Co Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Hunt (Capacitors) Ltd, A. H
Kandem Electrical Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
McKellan Automation Ltd
Marconi Instruments Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Salford Electrical Instruments Ltd
Sargrove Electronics Ltd
Standard Telephones & Cables Ltd
Stonebridge Electrical Instruments Ltd
Sullivan Ltd, H. W
Taylor Electrical Instruments Ltd
Thompson Ltd, J. Langham
Tinsley & Co Ltd, H
Walter's Electrical Mfg Co Ltd
Wayne Kerr Laboratories Ltd

Bridges—conductivity
★ Circle *No 42* on reply card
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Mullard Equipment Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd

Bridges—d.c
★ Circle *No 43* on reply card
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
Baldwin Instruments Co Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Lintronic Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Microcell Electronics
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Wayne Kerr Laboratories Ltd
Wykeham & Co Ltd, W

Bridges—impedance
★ Circle *No 44* on reply card
Allied Electronics Ltd
Aveley Electric Ltd
Avo Ltd
B & K Laboratories Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Clare Instrument Co Ltd
Dawe Instruments Ltd
Emeco Electronics Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Hatfield Instruments Ltd
Instruments & Controls Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
Marconi Instruments Ltd
McKellen Automation Ltd
Muirhead & Co Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Standard Telephones & Cables Ltd
Solartron Electronic Group Ltd, The
Stonebridge Electrical Co Ltd, The
Sullivan Ltd, H. W
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd

Bridges—inductance
★ Circle *No 45* on reply card
Aveley Electric Ltd
Avo Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Dawe Instruments Ltd
Emeco Electronics Ltd
Farnell Instruments Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Hatfield Instruments Ltd
Instruments & Controls Ltd
Kandem Electrical Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
McKellen Automation Ltd
Marconi Instruments Ltd
Muirhead & Co Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Samwell & Hutton Ltd
Southern Instruments Computer Division
Standard Telephones & Cables Ltd

★ *For further details circle on card facing page A60*

Saunders-Roe Ltd
Sullivan Ltd, H. W
Sunvic Controls Ltd
Teledictor Ltd
Thompson Ltd, J. Langham
Tinsley & Co Ltd, H.
Tripletone Mfg Co Ltd
Venner Electronics Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Amplifiers—hydraulic
★ Circle *No 15* on reply card
Elliott Bros (London) Ltd
Fairey Aviation Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Solartron Electronic Group Ltd, The

Amplifiers—magnetic
★ Circle *No 16* on reply card
Addison Electric Co Ltd
Amos (Electronics) Ltd
Andec Ltd
Appleby & Ireland Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
British Thomson-Houston Co Ltd, The
Broadcast & Acoustic Equipment Co Ltd
CJR Electrical & Electronic Developments Ltd
Corex Communications Equipment (1948) Ltd
De Havilland Propellors Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Express Winding Co
Fortiphone Ltd
Foster Transformers Ltd
GB-Kalee Ltd
General Electric Co Ltd, The
Gresham Transformers Ltd
Gloster Aircraft Co Ltd
Haddon Transformers Ltd
Hatfield Instruments Ltd
Hirst Electronic Ltd
Holgate of Totton Ltd
Hymatic Engineering Co Ltd, The
Igranic Electric Co Ltd
JD Electronics Ltd
Kershaw & Sons Ltd, A
Ketay Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Lee Products (GB) Ltd
Lion Electronic Developments Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Morris Electrical Engineering Co Ltd, John
PAR Ltd
Parmeko Ltd
Plessey Developments Co Ltd
Pullin & Co Ltd, R. B
Pye & Co Ltd, W. G
Racal Engineering Ltd
Rivlin Instruments Ltd
Sanders (Electronics) Ltd, W. H
Servomex Controls Ltd
Sperry Gyroscope Co Ltd
Stonebridge Electrical Co Ltd, The
Tannoy Products Ltd
Teddington Aircraft Controls Ltd
Telefusion (Engineering) Ltd
Tellux Ltd
Testgear Components (London) Ltd
Ultra Electric Ltd
Vernons Industries Ltd
Welmec Corporation Ltd
Westool Ltd
West Instruments Ltd
Winston Electronics Ltd

Amplifiers—miscellaneous
★ Circle *No 17* on reply card
Amplivox Ltd
Appleby & Ireland Ltd
Aveley Electric Ltd
Barr & Stroud Ltd
British Physical Laboratories
Cawkell Research & Electronics Ltd
Cossor Instruments Ltd
Craven Electronics Ltd
Dynatron Radio Ltd
Ericsson Telephones Ltd
General Electric Co Ltd, The
Joyce, Loebel & Co Ltd
Kelvin & Hughes Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Microwave Instruments Ltd
Pye & Co. Ltd, W. G
Rank Cintel Ltd
Sperry Gyroscope Co Ltd
Solartron Electronic Group Ltd, The
Sunvic Controls Ltd

Amplifiers—pneumatic
★ Circle *No 18* on reply card
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Electro Methods Ltd
Gordon & Co Ltd, James
Hymatic Engineering Co Ltd, The
Kent Ltd, George
Negretti & Zambra Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Telektron Ltd
Teddington Aircraft Controls Ltd

Amplifiers—r.f
★ Circle *No 19* on reply card
Allied Electronics Ltd
Amos (Electronics) Ltd
Andec Ltd
Avo Ltd
Aveley Electric Ltd
Cawkell Research & Electronics Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
EMI Electronics Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
General Radiological Ltd
Hifi Ltd
Kandem Electrical Ltd
Kent Ltd, George
Leland Instruments Ltd
Livingston Laboratories Ltd
Lancashire Dynamo Electronic Products Ltd
Nagard Ltd
PAR Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Racal Engineering Ltd
Robinson & Partners Ltd, F. C
Smurthwaite Electronics
Solartron Electronic Group Ltd, The
SS Electronics Ltd
Standard Telephones & Cables Ltd
Sullivan Ltd, H. W

Amplifiers—rotating machine
★ Circle *No 20* on reply card
British Thompson-Houston Co Ltd, The
English Electric Co Ltd, The
Macfarlane Engineering Co Ltd
Metropolitan-Vickers Electrical Co Ltd, The
Vernons Industries Ltd

Annunciators
★ Circle *No 21* on reply card
Chamberlain Industries Ltd
Magnetic Controls Ltd
Panellit Ltd
Standard Telephones & Cables Ltd
Sunvic Controls Ltd
WS Electronics (Production) Ltd

Anti-vibration apparatus
★ Circle *No 22* on reply card
AVA Ltd
Baird & Tatlock Ltd
BTR Industries Ltd
Cambridge Instrument Co Ltd
Cementation (Muffelite) Ltd
Clayton-Wright Ltd, Howard
Cooper & Co (Birmingham) Ltd
Cork Mfg Co Ltd
Dunlop Special Products Ltd
Expanded Rubber Co Ltd
Fenner & Co Ltd, J. H
Griffin & George Ltd
Knitted Mesh Mfg Co Ltd
Metalastik Ltd (Mountings)
Mitchell & Snow Ltd, N. W
Rubber Bonders Ltd
Silentbloc Ltd
Smiths Aircraft Instruments Ltd
Towers & Co Ltd, J. W
Wildbore Ltd, J. E.
Wilkinson Rubber Linatex Ltd

Balances—analytical
★ Circle *No 23* on reply card
Avery Ltd, W. & T
Baird & Tatlock (London) Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Nicolson (Scientific Instruments) Ltd, W. B
Oertling Ltd, L
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balances—micro-chemical
★ Circle *No 24* on reply card
Baird & Tatlock (London) Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Oertling Ltd, L
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balances—automatic weighing
★ Circle *No 25* on reply card
Avery Ltd, W. & T
B & K Laboratories Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Nash & Thompson Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Western Mfg (Reading) Ltd

Balances—weight (precision)
★ Circle *No 26* on reply card
Avery Ltd, W. & T
Baird & Tatlock (London) Ltd
Cuthbert Ltd, Ralph
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Hilger & Watts Ltd
Nash & Thompson Ltd
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balances—aperiodic
★ Circle *No 27* on reply card
Avery Ltd, W. & T
Baird & Tatlock (London) Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Oertling Ltd, L
Shandon Scientific Co Ltd
Stanton Instruments Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Vicsons Ltd
Webb Ltd, William A

Balancing machines—dynamic
★ Circle *No 28* on reply card
Avery Ltd, W. & T
British Thomson-Houston Co Ltd, The
Burton, Griffiths & Co Ltd
Dawe Instruments Ltd
EMI Ltd
EMI Electronics Ltd
Farnell Instruments Ltd
Geisler Ltd, C. F. R
Griffin & George Ltd
Herbert Ltd, Alfred
Herbert Ltd, Edward G
Jackson & Bradwell Ltd
Livingston Laboratories Ltd
Lock Ltd, A. M
LMK Mfg Co Ltd
Pullin & Co Ltd, R. B
Reid & Sigrist Ltd
Robinson & Partners Ltd, F. C
Samwell & Hutton Ltd
Small Electric Motors Ltd
Solartron Electronic Group Ltd, The
Test Equipment Ltd
Western Mfg (Reading) Ltd
Weyco Equipment Ltd
Wickman Ltd

Balancing machines—static
★ Circle *No 29* on reply card
Avery Ltd, W. & T
Burton, Griffiths & Co Ltd
Reid & Sigrist Ltd
Wickman Ltd

Ball bearings—miniature
★ Circle *No 30* on reply card
BMB (Sales) Ltd
British Timken Ltd
Dick Ltd, R. & J
EMO Instrumentation Ltd (Precision)
Fischer Bearings Co Ltd
Gurney & New Ltd
Hallmac Tools Ltd
Hoffman Mfg Co Ltd
International Engineering Concessionaires Ltd
London V-Rope Drive Co
Melvin Bros Ltd
Miniature Bearings Ltd
Quality Bearings Ltd
Ransome & Marles Bearing Co Ltd
Reid & Sigrist Ltd
Rye Bearings, Claude
Skefco Ball Bearing Co Ltd
Smith & Grace Ltd
Spiro Ball Bearing Co Ltd
Tormo Ltd
Townson & Mercer Ltd
Universal Ball Bearing Repair & Mfg Co Ltd
Warden & Co Ltd, A

Batteries—dry
★ Circle *No 31* on reply card
Alpha Accessories Ltd
Atlas Carbon & Battery Co Ltd
Burndept Ltd
Chloride Batteries Ltd
EMI Ltd
Ever Ready Co (Gt Britain) Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Le Carbone (Gt Britain) Ltd
Livingston Laboratories Ltd
Mallory Batteries Ltd
Oldham & Son Ltd
Siemens Edison Swan Ltd
Silvertown Rubber Co Ltd

★ *For further details circle on card facing page 460*

Sterdy Telephones Ltd
Vidor Ltd
Varley Dry Accumulators Ltd

Batteries—mercury
★ Circle *No 32* on reply card
Burndept Ltd
Mallory Batteries Ltd
Vidor Ltd

Batteries—solar
★ Circle *No 33* on reply card
B & K Laboratories Ltd
Livingston Laboratories Ltd

Batteries—storage
★ Circle *No 34* on reply card
Alton Battery Co Ltd, The
Britannia Batteries Ltd
British Electrical & Mfg Co Ltd
Brooke Industries Ltd
CAV Ltd
Chloride Batteries Ltd
Christie & Sadler Ltd
Crompton Parkinson Ltd
Diamex Ltd
DP Battery Co Ltd, The
Dunlop (Battery) Co Ltd
Gnu Accumulator Co Ltd
Lucas Ltd, Joseph
Mine & Safety Appliances Co Ltd
Nife Batteries
Oldham & Son Ltd
Palmer Ltd, G. A. Stanley
Peto & Radford Ltd
Pritchett & Gold & EPS Co Ltd
Radenite Batteries Ltd
Siemens Edison Swan Ltd
Tudor Accumulator Co Ltd
Tungstone Products Ltd
Varley Dry Accumulators Ltd
Venner Accumulators Ltd

Bellows—metallic
★ Circle *No 35* on reply card
Appleby & Ireland Ltd
Avica Equipment Ltd
Drayton Regulator & Instrument Co Ltd
Griffin & George Ltd
Leybold Vacuum Sales Ltd
Palatine Tool & Engineering Co (Surbiton) Ltd
Power Flexible Tubing Co Ltd, The
Samson Controls (London) Ltd
Teddington Aircraft Controls Ltd

Bellows—non-metallic
★ Circle *No 36* on reply card
Appleby & Ireland Ltd
Beakbane (Fortox) Ltd, Henry
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Helvetia Leather Co Ltd
Hall & Hall Ltd
Townson & Mercer Ltd

Boiler controls & instrumentation
★ Circle *No 37* on reply card
Accurate Recording Instrument Co Ltd
Airflow Developments Ltd
Appleby & Ireland Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
Black Automatic Controls Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Cass & Phillip Ltd
Colostat Combustion Systems Ltd
Combustion Equipment Ltd
DEV Engineering Co Ltd
Danfoss Mfg Co
De La Rue & Co Ltd, Thomas (Potterton Division)
Elcontrol Ltd
Electroflo Meters Co Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Ether Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Fireye Controls Ltd
Foxboro-Yoxall Ltd
Foster Instrument Co Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Ionic Instruments (London) Ltd
JV Radio & Television Ltd
Kandem Electrical Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Metropolitan Engineering Co Ltd
Metropolitan-Vickers Electrical Co Ltd
Nalder Bros & Thompson Ltd
Nash & Thompson Ltd
Parkinson & Cowan Instruments
Perl Controls Ltd
Pye & Co Ltd, W. G
Radiovisor Parent Ltd
Reavell & Co
Rheostatic Co Ltd,, The
Samson Controls (London) Ltd
Sauter Controls Ltd
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Teleflex Products Ltd
Thermocontrol Installations Co Ltd
Thompson Instruments Co Ltd, John
Trist & Co Ltd, Ronald
Tylors of London Ltd
Wykeham & Co Ltd, W

Bolometers
★ Circle *No 38* on reply card
Aveley Electric Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Livingston Laboratories Ltd
Standard Telephones & Cables Ltd

Bourdon—tubes
★ Circle *No 39* on reply card
Accles & Pollock Ltd
Appleby & Ireland Ltd
Booth & Co Ltd, James
Cambridge Instrument Co Ltd
Crosby Valve & Engineering Co Ltd
Johnson, Matthey & Co Ltd
KDG Instruments Ltd
Teddington Aircraft Controls Ltd

Bridges—a.c
★ Circle *No 40* on reply card
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Croydon Precision Instrument Co
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Lintronic Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Microcell Electronics
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
New Electronic Products Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Wayne Kerr Laboratories Ltd
Welmec Corporation Ltd
Wykeham & Co Ltd, W

Bridges—capacitance
★ Circle *No 41* on reply card
Allied Electronics Ltd
Amos (Electronics) Ltd
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
B & K Laboratories Ltd
BPL (Instruments) Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Clare Instrument Co Ltd
Copper & Alloys Ltd
Croydon Precision Instrument Co
Dawe Instruments Ltd
Doran Instrument Co Ltd
Electrical Instrument Co (Hillingston) Ltd, The
Emeco Electronics Ltd
EMI Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Furzehill Laboratories Ltd
Fielden Electronics Ltd
Gambrell Bros & Co Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Hunt (Capacitors) Ltd, A. H
Kandem Electrical Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
McKellan Automation Ltd
Marconi Instruments Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Salford Electrical Instruments Ltd
Sargrove Electronics Ltd
Standard Telephones & Cables Ltd
Stonebridge Electrical Instruments Ltd
Sullivan Ltd, H. W
Taylor Electrical Instruments Ltd
Thompson Ltd, J. Langham
Tinsley & Co Ltd, H
Walter's Electrical Mfg Co Ltd
Wayne Kerr Laboratories Ltd

Bridges—conductivity
★ Circle *No 42* on reply card
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Mullard Equipment Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd

Bridges—d.c
★ Circle *No 43* on reply card
Aveley Electric Ltd
Avo Ltd
Bailey Meters & Controls Ltd
Baldwin Instruments Co Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Lintronic Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Microcell Electronics
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Wayne Kerr Laboratories Ltd
Wykeham & Co Ltd, W

Bridges—impedance
★ Circle *No 44* on reply card
Allied Electronics Ltd
Aveley Electric Ltd
Avo Ltd
B & K Laboratories Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Clare Instrument Co Ltd
Dawe Instruments Ltd
Emeco Electronics Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Hatfield Instruments Ltd
Instruments & Controls Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
Marconi Instruments Ltd
McKellen Automation Ltd
Muirhead & Co Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Standard Telephones & Cables Ltd
Solartron Electronic Group Ltd, The
Stonebridge Electrical Co Ltd, The
Sullivan Ltd, H. W
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd

Bridges—inductance
★ Circle *No 45* on reply card
Aveley Electric Ltd
Avo Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Dawe Instruments Ltd
Emeco Electronics Ltd
Farnell Instruments Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Hatfield Instruments Ltd
Instruments & Controls Ltd
Kandem Electrical Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
McKellen Automation Ltd
Marconi Instruments Ltd
Muirhead & Co Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Samwell & Hutton Ltd
Southern Instruments Computer Division
Standard Telephones & Cables Ltd

★ *For further details circle on card facing page A60*

Stonebridge Electrical Co Ltd, The
Sullivan Ltd, H. W.
Tinsley & Co Ltd, H.
Wayne Kerr Laboratories Ltd

Bridges—power factor
★ Circle *No 46* on reply card
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Livingston Laboratories Ltd

Bridges—resistance
★ Circle *No 47* on reply card
Aveley Electric Ltd
Avo Ltd
B & K Laboratories Ltd
Baldwin Instrument Co Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Clare Instrument Co Ltd
Croydon Precision Instrument Co
Cuthbert Ltd, Ralph
Dawe Instruments Ltd
Doran Instrument Co Ltd
Electrical Instrument Co (Hillington) Ltd, The
Electronic Switchgear (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Foster Instrument Co Ltd
Gambrell Bros & Co Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Hunt (Capacitors) Ltd, A. H
Instruments & Controls Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
McKellen Automation Ltd
Measuring Instruments (Pullin) Ltd
Muirhead & Co Ltd
Mullard Ltd
Nash & Thompson Ltd
New Electronic Products Ltd
Nicholson (Scientific Instruments) Ltd, W. B
Pye & Co Ltd, W. G
Rank Cintel Ltd
Robinson & Partners Ltd, F. C
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Standard Telephones & Cables Ltd
Sullivan Ltd, H. W
Taylor Electrical Instruments Ltd
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd

Bridges—schering
★ Circle *No 48* on reply card
Aveley Electric Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Croydon Precision Instrument Co
Emeco Electronics Ltd
Griffin & George Ltd
Kandem Electrical Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Robinson & Partners Ltd, F. C
Research & Control Instruments Ltd
Sullivan Ltd, H. W
Tinsley & Co Ltd, H

Bridges—self-balancing
★ Circle *No 49* on reply card
B & K Laboratories Ltd
Fielden Electronics Ltd
Lancashire Dynamo Electronic Products Ltd

Bridges—strain gauge
★ Circle *No 50* on reply card
Appleby & Ireland Ltd
B & K Laboratories Ltd
Elliott Bros (London) Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Leland Instruments Ltd
Lock & Co Ltd, A. M
McKellen Automation Ltd
Research & Control Instruments Ltd
Savage & Parsons Ltd
Tinsley & Co Ltd, H
Thompson Ltd, J Langham

Bridges—universal
★ Circle *No 51* on reply card
Allied Electronics Ltd
Avo Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Dawe Instruments Ltd
Doran Instrument Co Ltd
Griffin & George Ltd
Kandem Electrical Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Mullard Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Stonebridge Electrical Co Ltd, The
Sullivan Ltd, H. W

Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd

Bridges—wattmeter
★ Circle *No 52* on reply card
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Crompton Parkinson Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
General Electric Co Ltd, The
Livingston Laboratories Ltd
Marconi Instruments Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Nalder Bros & Thompson Ltd
Sangamo Weston Ltd

Calling systems
★ Circle *No 53* on reply card
Amplivox Ltd
Autophone Ltd
Easco Electrical (Holdings) Ltd
Fonadek (Branson) Ltd
General Electric Co Ltd, The
JV Radio & Television Ltd
Klaxon Ltd
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd

Cameras—high speed
★ Circle *No 54* on reply card
Airtech Ltd
Avimo Ltd
Barnet Ensign Ltd
Ilford Ltd
Kodak Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Nash & Thompson Ltd
Thompson Ltd, J Langham
Vinten Ltd, W
Weyers Bros Ltd
Wray (Optical Works) Ltd
Winston Electronics Ltd

Cameras—oscilloscope recording
★ Circle *No 55* on reply card
Airmec Ltd
Cossor Instruments Ltd
EMI Electronics Ltd
Fairey Aviation Co Ltd, The
Livingston Laboratories Ltd
Mullard Equipment Ltd
Nagard Ltd
New Electronic Products Ltd
Pye & Co Ltd, W. G
Rank Cintel Ltd
Savage & Parsons Ltd
Shackman & Sons Ltd, D
Southern Instruments Computer Division
Thompson Ltd, J. Langham
Wykeham & Co Ltd, W

Choppers
★ Circle *No 56* on reply card
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Honeywell Controls Ltd
Joyce, Loebl & Co Ltd
Kent Ltd, George
Livingston Laboratories Ltd
Nash & Thompson Ltd
PAR Ltd
Parkinson & Cowan Instruments
Research & Control Instruments Ltd
Sargrove Electronics Ltd
Solartron Electronic Group Ltd, The
Telephone Mfg Co Ltd, The
Wright & Weaire Ltd

Clutches—magnetic particle
★ Circle *No 57* on reply card
Bruce Peebles & Co Ltd
Burnand & Son Ltd, W. E
Comucate Ltd
Electromagnets Ltd
General Electric Co Ltd, The
Igranic Electric Co Ltd
Magnetic Equipment Co Ltd, The
Rapid Magnetic Machines Ltd
Simmons Electrical & Winding Co Ltd
Sperry Gyroscope Co Ltd
Westool Ltd

Combustion controls—automatic
★ Circle *No 58* on reply card
Babcock & Wilcox Ltd
Bailey Meters & Controls Ltd
Black Automatic Controls Ltd
Bristol's Instrument Co Ltd
Cass & Phillip Ltd
Danfoss Mfg Co
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Goroon & Co Ltd, James
Honeywell-Brown Ltd
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd

Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Metropolitan-Vickers Electrical Co Ltd
Perl Controls Ltd
Radiovisor Parent Ltd
Rheostatic Co Ltd, The
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd

Comparators—colour
★ Circle *No 59* on reply card
Baldwin Instrument Co Ltd
Bellingham & Stanley Ltd
B & K Laboratories Ltd
Camlab (Glass) Ltd
Evans Electroselenium Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Hearson & Co Ltd, Charles
Joyce, Loebel & Co Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Tinsley & Co Ltd, H
Tintometer Co Ltd
Townson & Mercer Ltd

Comparators—electrical
★ Circle *No 60* on reply card
Electrical Instrument Co (Hillington) Ltd, The
Fielden Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Herbert Ltd, Alfred
Sigma Instrument Co Ltd
Taylor, Taylor & Hobson Ltd
Tinsley & Co Ltd, H
Vernon Instrument Co Ltd

Comparators—electronic
★ Circle *No 61* on reply card
Advance Components Ltd
Andec Ltd
Aveley Electric Ltd
Automatic Telephone & Electric Co Ltd
B & K Laboratories Ltd
Dependable Relay Co
EMI Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Lion Electronic Developments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Mollart Engineering Co Ltd
Phillips & Bonson Ltd
Rank Cintel Ltd
Robinson & Partners, F. C
Reilly Engineering Ltd
Sargrove Electronics Ltd
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd
Southern Instruments Computer Division
Teledictor Ltd
Wayne Kerr Laboratories Ltd

Comparators—impedance
★ Circle *No 62* on reply card
Allied Electronics Ltd
British Physical Laboratories
Dawe Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Lion Electronic Developments Ltd
Robinson & Partners Ltd, F. C
Solartron Electronic Group Ltd, The

Comparators—mechanical
★ Circle *No 63* on reply card
Baty & Co Ltd, J. E
Cambridge Instrument Co Ltd
Engineering Products Ltd
Herbert Ltd, Alfred
Mercer Ltd, Thomas
Mollart Engineering Co Ltd
Precision Tool & Instrument Co Ltd
Sigma Instrument Co Ltd
Vernon Instrument Co Ltd

Comparators—pneumatic
★ Circle *No 64* on reply card
British Thermostat Co Ltd
Herbert Ltd, Alfred
Mercer Ltd, Thomas
Sigma Instrument Co Ltd
Sunvic Controls Ltd
Wickman Ltd

Computer test equipment
★ Circle *No 65* on reply card
B & K Laboratories Ltd
Cawkell Research & Electronics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Ferranti Ltd
Lintronic Ltd
Livingston Laboratories Ltd
Metrix Instruments Ltd
Microcell Electronics
Mullard Equipment Ltd
Rank Cintel Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Taylor Electrical Instruments Ltd
Wayne Kerr Laboratories Ltd
Weyers Bros Ltd
Winston Electronics Ltd
Wykeham & Co Ltd, W

★ *For further details circle on card facing page A60*

Computers—analogue

★ Circle No 66 on reply card

Air Trainers Link Ltd
Airmec Ltd
Dowty Nucleonics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Fairey Aviation Co Ltd, The
Ferranti Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Ltd
Nash & Thompson Ltd
Pullin & Co Ltd, R. B
Pye & Co Ltd, W. G
Saunders-Roe Ltd
Short Bros & Harland Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
Sunvic Controls Ltd
Weyers Bros Ltd
Winston Electronics Ltd

Computers—digital

★ Circle No 67 on reply card

British Tabulating Machine Co Ltd, The
Dowty Nucleonics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ferranti Ltd
IBM (United Kingdom) Ltd
Leland Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Ltd
Power-Samas Accounting Machines Ltd
Pye & Co Ltd, W. G
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Standard Telephones & Cables Ltd
Sunvic Controls Ltd
Weyers Bros Ltd

Conductivity—indicators, recorders and controllers

★ Circle No 68 on reply card

Bailey Meters & Controls Ltd
Cambridge Instrument Co Ltd
Doran Instrument Co Ltd
Elcontrol Ltd
Elga Products Ltd
Electronic Switchgear (London) Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Ether Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foxboro-Yoxall Ltd
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Ionic Instruments (London) Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Measuring Instruments (Pullin) Ltd
Mullard Equipment Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Radiovisor Parent Ltd
Record Electrical Co Ltd, The
Thermocontrol Installations Co Ltd
Tinsley & Co Ltd, H
Sargrove Electronics Ltd
Wayne Kerr Laboratories Ltd

Contactors

★ Circle No 69 on reply card

Airedale Electrical Mfg Co Ltd
Allen West & Co Ltd
Allis-Chalmers (Gt Britain) Ltd
Arrow Electric Switches Ltd
Belmos Co Ltd
Besson & Robinson Ltd
Bray Ltd, E. N
British Federal Welder & Machine Co Ltd
British Klockner Switchgear Ltd
British Thermostat Co Ltd
British Thomson-Houston Co Ltd, The
CNS Instruments Ltd
Colne Switchgear Ltd
Contactor Switchgear Ltd
Danfoss Mfg Co
Dewhurst & Partners Ltd
Donovan Electrical Co Ltd, The
Ega Electric Ltd
Electric Construction Co Ltd, The
Electrical Apparatus Co Ltd
Electro-Magnetic Control Co
Electro Methods Ltd
Electro-Mechanical Mfg Co Ltd
EMB Co Ltd
Engel & Gibbs Ltd
Erskine, Heap & Co Ltd
Geipel Ltd, William
General Electric Co Ltd, The
GWB Furnaces Ltd
Hendrey Relays Ltd
Hirst Electronics Ltd
Igranic Electric Co Ltd
Kingston Control Systems Ltd
Klöckner-Moeller England Ltd
Lancashire Dynamo Nevelin Ltd
Laurence, Scott & Electromotors Ltd
Londex Ltd
Magnet Engineering Co, The
Magnetic Devices Ltd
M & C Switchgear Ltd
Metropolitan-Vickers Electrical Co Ltd
Midland Electric Mfg Co Ltd
Morgan Crucible Co Ltd
Morris Electrical Engineering Co Ltd, John
MTE Control Gear Ltd
Nalder Bros & Thompson Ltd
Nottingham Thermometer Co Ltd
Partridge Wilson & Co Ltd
Power Equipment Co Ltd
Process Control Gear Ltd
Rheostatic Co Ltd, The
Sanders (Electronics) Ltd, W. H (Static)
Santon Ltd
Sauter Controls Ltd
Sharp Control Gear Ltd
Siemens-Schuckert (Gt Britain) Ltd
South London Electrical Equipment Co Ltd
Square D Ltd
Sterdy Telephones Ltd
Sunvic Controls Ltd
Universal Control Equipment Ltd
Varilectric Ltd
Vlasto, Clark & Watson Ltd
West Instrument Ltd
Watford Electric & Mfg Co Ltd

Control installation engineers

★ Circle No 70 on reply card

Associated Automation Ltd
Bailey Meters & Controls Ltd
B & K Laboratories
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
CNS Instruments Ltd
Constructors—John Brown Ltd
Craven Electronics Ltd
Dunford & Elliott (Sheffield) Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Evershed & Vignoles Ltd
Falk & Co Ltd, M
Fischer & Porter Ltd
Fisher Governor Co Ltd
Glass Developments Ltd
Gordon & Co Ltd, James
Hall & Co Ltd, Matthew
Hutcheon Duthie & Son Ltd, R
Instrument Installation Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
KDG Instruments Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Joyce, Loebl & Co Ltd
Livingston Laboratories Ltd
Lancashire Dynamo Electronic Products Ltd
Mead & Phasey Ltd
Microcell Electronics
New Western (Engineering) Ltd
Negretti & Zambra Ltd
Nuclear Research Applications Ltd
Planer Ltd, G. V
Pye & Co Ltd, W. G
Robinson & Partners Ltd, W. G
Sargrove Electronics Ltd
Saunders-Roe Ltd
Solartron Electronic Group Ltd, The
Sunvic Controls
Telecommunication Instruments Ltd
Telektron (GB) Ltd
Taylor Controls
Thermocontrol Installations Co Ltd
Universal Control Equipment Ltd
Watson & Smith Ltd, John
Western Detail Mfrs Ltd
Western Mfg (Reading) Ltd
West Instrument Ltd

Convertors—analogue to digital

★ Circle No 71 on reply card

B & K Laboratories Ltd
Dunford & Elliott (Sheffield) Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
English Electric Co Ltd, The
Hilger & Watts Ltd
Ferranti Ltd
Ketay Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Equipment Ltd
Racal Engineering Ltd
Solartron Electronics Group Ltd, The
Southern Instruments Computer Division
Sunvic Controls Ltd

Counters—batch

★ Circle No 72 on reply card

Airmec Ltd
Allied Electronics Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
Associated Automation Ltd
Boulton Paul Aircraft Ltd
British Thomson-Houston Co Ltd, The
Burndept Ltd
Carter & Co Ltd, B. & F
Cass & Phillip Ltd
Counting Instruments Ltd
Dunford & Elliott (Sheffield) Ltd
Dowty Nucleonics Ltd
Ekco Electronics Ltd
Elcontrol Ltd
Electronic Machine Co Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Ericsson Telephones Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Isotope Developments Ltd
Kent Ltd, George
Labgear Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Londex Ltd
McKellen Automation Ltd
Measuring Instruments (Pullin) Ltd
Marconi Instruments Ltd
Mullard Ltd
Pye & Co Ltd, W. G
Racal Engineering Ltd
Radiovisor Parent Ltd
Rank Cintel Ltd
Robinson & Partners Ltd, F. C
Smiths Industrial Instrument Division
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Teledictor Ltd
Thompson Ltd, J. Langham
Trumeter Co Ltd
Venner Electronics Ltd
Western Mfg (Reading) Ltd

Counters—binary

★ Circle No 73 on reply card

Airmec Ltd
B & K Laboratories Ltd
Dowty Nucleonics Ltd
Dunford & Elliott (Sheffield) Ltd
Electro Methods Ltd
Electronic Machine Co Ltd
EMI Electronics Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Londex Ltd
Measuring Instruments (Pullin) Ltd
Racal Engineering Ltd
Rank Cintel Ltd
Stonebridge Electrical Co Ltd, The
Solartron Electronic Group Ltd, The
Venner Electronics Ltd

Counters—decade

★ Circle No 74 on reply card

Airmec Ltd
Associated Automation Ltd
B & K Laboratories Ltd
Counting Instruments Ltd
Dunford & Elliott ((Sheffield) Ltd
Dowty Nucleonics Ltd
Ekco Electronics Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Londex Ltd
Marconi Instruments Ltd
Measuring Instruments (Pullin) Ltd
Mullard Ltd (Tubes)
Racal Engineering Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Radiovisor Parent Ltd
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The
Teledictor Ltd
Thompson Ltd, J. Langham
Venner Electronics Ltd

Counters—electrical impulse

★ Circle No 75 on reply card

Airmec Ltd
Associated Automation Ltd
British Tabulating Machine Co Ltd
B & K Laboratories Ltd
Carter & Co Ltd, B. & F
Cass & Phillip Ltd
Counting Instruments Ltd

★ *For further details circle on card facing page A60*

Davis (Relays) Ltd, Jack
Dobbie McInnes Ltd
Dowty Nucleonics Ltd
Dunford & Elliott (Sheffield) Ltd
Elcontrol Ltd
Electrical Remote Control Co Ltd
Electronic Machine Co Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
General Radiological Ltd
Hall (Elec Engineers) Ltd, J. Edward
Instruments & Controls Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Labgear Ltd
Londex Ltd
Lock & Co Ltd, A. M
Leland Instruments Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Racal Engineering Ltd
Radiovisor Parent Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The
Smiths Industrial Instrument Division
Trumeter Co Ltd
Thompson Ltd, J. Langham
Venner Electronics Ltd
Western Mfg (Reading) Ltd
Winston Electronics Ltd

Counters—electronic
★ Circle *No 76* on reply card
Airmec Ltd
Amos (Electronics) Ltd
Andec Ltd
Associated Automation Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Boulton Paul Aircraft Ltd
British Tabulating Machine Co Ltd
British Thomson-Houston Co Ltd, The
Burndept Ltd
Cass & Phillip Ltd
Dowty Nucleonics Ltd
Ekco Electronics Ltd
Elcontrol Ltd
Electronic Switchgear (London) Ltd
Elliott Bros (London) Ltd
Emeco Electronics Ltd
EMI Electronics Ltd
Ericsson Telephones Ltd
Farnell Instruments Ltd
Gate Electronics Ltd
General Radiological Ltd
Hatfield Instruments Ltd
Hobson Ltd, H. M
Isotope Developments Ltd
Joyce, Loebl & Co Ltd
Labgear Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Lintronic Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Londex Ltd
Marconi Instruments Ltd
Microcell Electronics
Mullard Ltd
Panax Equipment Ltd
Racal Engineering Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Radiovisor Parent Ltd
Robinson & Partners Ltd, F. C
Sargrove Electronics Ltd
Saunders-Roe Ltd
Solartron Electronic Group Ltd, The
Telecommunication Instruments Ltd
Teledictor Ltd
Thompson Ltd, J. Langham
Venner Electronics Ltd
Western Mfg (Reading) Ltd
Winston Electronics Ltd

Counters—mechanical
★ Circle *No 77* on reply card
Associated Automation Ltd
Carter & Co Ltd, B. & F
Cass & Phillip Ltd
Counting Instruments Ltd
Dobbie McInnes Ltd
Elliott Bros (London) Ltd
English Numbering Machines Ltd
Ericsson Telephones Ltd
Findlay & Co
Foundrometers Ltd
Glass Developments Ltd
Hearson & Co Ltd, Charles
Kent Ltd, George
Leland Instruments Ltd
Londex Ltd
McKellen Automation Ltd
Panax Equipment Ltd
Research & Control Instruments Ltd
Smiths Industrial Instrument Division
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The
Trumeter Co Ltd
Weyers Bros Ltd

Counters—photocell
★ Circle *No 78* on reply card
Airmec Ltd
Cass & Phillip Ltd
Counting Instruments Ltd
Dunford & Elliott (Sheffield) Ltd
Elcontrol Ltd
Electronic Machine Co Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Londex Ltd
Mullard Ltd (Tubes)
Racal Engineering Ltd
Rank Cintel Ltd
Teledictor Ltd
Thompson Ltd, J. Langham
Venner Electronics Ltd

Counters—radiation
★ Circle *No 79* on reply card
Airmec Ltd
B & K Laboratories Ltd
Burndept Ltd
Ekco Electronics Ltd
Ericsson Telephones Ltd
General Radiological Ltd
Isotope Developments Ltd
Lock & Co Ltd, A. M
Mullard Ltd (Tubes)
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
"Solus" Electronic Tubes Ltd, The

Counters—revolution
★ Circle *No 80* on reply card
Airmec Ltd
Allied Electronics Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
Associated Automation Ltd
Burndept Ltd
Carter & Co Ltd, B. & F
Craven Electronic Instrument Co Ltd
Counting Instruments Ltd
Dawe Instruments Ltd
Dowty Nucleonics Ltd
Dunford & Elliott (Sheffield) Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Numbering Machines Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Foundrometers Ltd
Griffin & George Ltd
Icknield Engineering Co Ltd
Instruments & Controls Ltd
Lancashire Dynamo Electronic Products Ltd
Labgear Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Mullard Ltd
Plessey Co Ltd, The
Pye & Co Ltd, W. G
Racal Engineering Ltd
Rank Cintel Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instrument Division
Solartron Electronic Group Ltd, The
Stonebridge Electrical Co Ltd, The
Thompson Ltd, J. Langham
20th Century Electronics Ltd
Trumeter Co Ltd
Weyers Bros Ltd

Counters—scintillation
★ Circle *No 81* on reply card
B & K Laboratories Ltd
Burndept Ltd
Ekco Electronics Ltd
EMI Electronics Ltd
ERD Engineering Co Ltd
Ericsson Telephones Ltd
Fleming Radio (Developments) Ltd
Falk & Co Ltd, M
General Radiological Ltd
Isotope Developments Ltd
Labgear Ltd
Lock & Co Ltd, A. M
Livingston Laboratories Ltd
Mervyn Instruments
Nuclear Enterprises (GB) Ltd
Panax Equipment Ltd
Plessey Nucleonics Ltd
Racal Engineering Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
20th Century Electronics Ltd

Current regulators
★ Circle *No 82* on reply card
Advance Components Ltd
Allied Electronics Ltd
All Power Transformers Ltd
Airmec Ltd
B & K Laboratories Ltd
British Electric Resistance Co Ltd
British Power Transformer Co Ltd
British Thomson-Houston Co Ltd, The
Electro Methods Ltd
Elliott Bros (London) Ltd
Foster Transformers Ltd
General Radiological Ltd
Kasama Electronics Ltd
Fielden Electronics Ltd
Harmsworth, Townley & Co
Hirst Electronic Ltd
Integra, Leeds & Northrup Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Morris Electrical Co Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Towers & Co Ltd, J. W

Curve followers
★ Circle *No 83* on reply card
Elliott Bros (London) Ltd
Lancashire Dynamo Electronic Products Ltd
Southern Instruments Computer Division

Data processing systems
★ Circle *No 84* on reply card
B & K Laboratories Ltd
British Tabulating Machine Co Ltd, The
British Thomson-Houston Co Ltd, The
Bulmers (Calculators) Ltd
Creed & Co Ltd
Data Recording Instrument Co Ltd
Digital Engineering Co Ltd
Dunford & Elliott (Sheffield) Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Fischer & Porter Ltd
Ferranti Ltd
Honeywell Controls Ltd
IBM (United Kingdom) Ltd
Kelvin & Hughes Ltd
Livingston Laboratories Ltd
Lancashire Dynamo Electronic Products Ltd
Mason & Sons Ltd, E. N
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Mullard Equipment Ltd
Panellit Ltd
Paul Ltd, K. S
Power-Samas Accounting Machines Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
Standard Telephones & Cables Ltd
Sunvic Controls Ltd
Western Mfg (Reading) Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Data transmission elements
★ Circle *No 85* on reply card
British Tabulating Machine Co Ltd, The
British Thomson-Houston Co Ltd, The
Brown Ltd, S. G
Creed & Co Ltd
Data Recording Instrument Co Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ferranti Ltd
Honeywell Controls Ltd
IBM (United Kingdom) Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Power-Samas Accounting Machines Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Smiths Aircraft Instruments Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
Sunvic Controls Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Densitometers
★ Circle *No 86* on reply card
Appleby & Ireland Ltd
Baldwin Instrument Co Ltd
Cambridge Instrument Co Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
Evans Electroselenium Ltd
Griffin & George Ltd
Hearson & Co Ltd, Charles
Hilger & Watts Ltd
Ilford Ltd
Ionic Instruments (London) Ltd
Joyce, Loebl & Co Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Nucleonic & Radiological Developments Ltd

Oldham & Sons Ltd
Radiovisor Parent Ltd
Salford Electrical Instruments Ltd
Shandon Scientific Co Ltd
Taylor Controls Ltd

Density controllers
★ Circle *No 87* on reply card
Bailey Meters & Controls Ltd
Bristol's Instrument Co Ltd
Crosby Valve & Engineering Co Ltd
Ekco Electronics Ltd
Electro-Magnetic Control Co
Evershed & Vignoles Ltd
Fisher Governor Co Ltd
Foxboro-Yoxall Ltd
Gordon & Co Ltd, James
Integra, Leeds & Northrup Ltd
Instruments & Controls Ltd
Isotope Developments Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Negretti & Zambra Ltd
Pye & Co Ltd, W. G
Reavell & Co
Sunvic Controls Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Townson & Mercer Ltd

Deviation meters
★ Circle *No 88* on reply card
Aveley Electric Ltd
B & K Laboratories Ltd
Craven Electronics Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Fielden Electronics Ltd
General Radiological Ltd
Honeywell Controls Ltd
Isotope Developments Ltd
Kent Ltd, George
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Plessey Nucleonics Ltd
Sunvic Controls Ltd

Differential pressure-controllers, indicators and recorders
★ Circle *No 89* on reply card
Accurate Recording Instrument Co
Airflow Developments Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Black Automatic Controls Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Crosby Valve & Engineering Co Ltd
Danfoss Mfg Co
Drayton Regulator & Instrument Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Fischer & Porter Ltd
General Electric Co Ltd, The
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
Hunt & Mitton Ltd
Hymatic Engineering Co Ltd, The
Integra, Leeds & Northrup Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Londex Ltd
Nash & Thompson Ltd
Negretti & Zambra Ltd
New Electronic Products Ltd
Nottingham Thermometer Co Ltd
Payne & Griffiths Ltd
Research & Control Instruments Ltd
Salford Electrical Instruments Ltd
Samson Controls (London) Ltd
Sauter Controls Ltd
Short & Mason Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instrument Division
Sperry Gyroscope Co Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Test Equipment Ltd
Thermocontrol Installations Co Ltd
Thompson Ltd, J. Langham
Wykeham & Co Ltd, W

Differential transformers
★ Circle *No 90* on reply card
Amos (Electronics) Ltd
Appleby & Ireland Ltd
Boulton Paul Aircraft Ltd
Craven Electronics Ltd
Elliott Bros (London) Ltd
Fielden Electronics Ltd
Instruments & Controls Ltd
Lancashire Dynamo Electronic Products Ltd
Pell Controls Ltd, Oliver
Research & Control Instruments Ltd
Sperry Gyroscope Co Ltd

Digital printers
★ Circle *No 91* on reply card
B & K Laboratories Ltd
British Tabulating Machine Co Ltd, The
Creed & Co Ltd
Dunford & Elliott (Sheffield) Ltd
Elliott Bros (London) Ltd
Ferranti Ltd
Hilger & Watts Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Racal Engineering Ltd
Sunvic Controls Ltd
Thompson Ltd, J. Langham

Digitised instruments
★ Circle *No 92* on reply card
Appleby & Ireland Ltd
B & K Laboratories Ltd
Dunford & Elliott (Sheffield) Ltd
Ericsson Telephones Ltd
Pullin & Co Ltd, R. B
Racal Engineering Ltd
Solartron Electronic Group Ltd, The
Thompson Ltd, J. Langham
Winston Electronics Ltd

Diodes—crystal—germanium etc
★ Circle *No 93* on reply card
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
English Electric Co Ltd, The
English Electric Valve Co Ltd
General Electric Co Ltd, The
Livingston Laboratories Ltd
Mullard Ltd
Plessey Co Ltd, The (Silicon)
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd
Texas Instruments Ltd (Silicon)
Winston Electronics Ltd

Display tubes—electrical and electronic
★ Circle *No 94* on reply card
Baldwin Instrument Co Ltd
English Electric Co Ltd, The
English Electric Valve Co Ltd
Ericsson Telephones Ltd
Ferranti Ltd
General Electric Co Ltd, The
Hilger & Watts Ltd
Mullard Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd

Distortion measuring equipment
★ Circle *No 95* on reply card
Airmec Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Dawe Instruments Ltd
EMI Electronics Ltd
Emeco Electronics Ltd
Fielden Electronics Ltd
Livingston Laboratories
Marconi Instruments Ltd
Microcell Electronics
Muirhead & Co Ltd
Phillips & Bonson Ltd
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd

Draught controllers and indicators
★ Circle *No 96* on reply card
Accurate Recording Instrument Co, The
Airflow Developments Ltd
Appleby & Ireland Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Drayton Regulator & Instrument Co Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Foxboro-Yoxall Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Negretti & Zambra Ltd
Nottingham Thermometer Co Ltd
Reavell & Co
Research & Control Instruments Ltd
Short & Mason Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Teleflex Products Ltd
Thermocontrol Installations Co Ltd

Dust detectors
★ Circle *No 97* on reply card
Airflow Developments Ltd
Birfield Industries Ltd
Craven Electronics Ltd
Endecotts (Filters) Ltd
Evans Electroselenium Ltd

Fleming Radio (Developments) Ltd
Gordon & Co Ltd, James
Griffin & George Ltd
Joyce, Loebl & Co Ltd
Lock & Co Ltd, A. M
Mine Safety Appliances Co Ltd
Nash & Thompson Ltd
Radiovisor Parent Ltd
Thermocontrol Installations Co Ltd

Engine indicators
★ Circle *No 98* on reply card
Allied Electronics Ltd
Cambridge Instrument Co Ltd
Cass & Phillip Ltd
Dobbie McInnes Ltd
Kandem Electrical Ltd
Lock & Co Ltd, A. M
Plessey Co Ltd, The
Smiths Aircraft Instruments Ltd
Southern Instruments Computer Division
Standard Telephones & Cables Ltd
Teddington Aircraft Controls Ltd

Epoxy Resins
★ Circle *No 99* on reply card
CIBA (Arl) Ltd
Shell Chemical Co Ltd

Facsimile telegraph equipment
★ Circle *No 100* on reply card
British Sarozal Ltd
Creed & Co Ltd
Muirhead & Co Ltd
Paul Ltd, K. S
Plessey Co Ltd, The
Racal Engineering Ltd
Solartron Electronic Group Ltd, The
Taylor Controls Ltd

Fade testing equipment
★ Circle *No 101* on reply card
Baldwin Instrument Co Ltd
Electronic Components
Kelvin & Hughes Ltd
Lock & Co Ltd, A. M

Fat blending instrumentation
★ Circle *No 102* on reply card
Elliott Bros (London) Ltd
Measurement Ltd

Ferrite materials & devices
★ Circle *No 103* on reply card
B & K Laboratories Ltd
Dubilier Condenser Co (1925) Ltd
Elliott Bros (London) Ltd
Ferranti Ltd
Microcell Electronics
Mullard Ltd
Plessey Co Ltd, The
Salford Electrical Instruments Ltd
Standard Telephones & Cables Ltd
Sanders (Electronics) Ltd, W. H

Filters—air
★ Circle *No 104* on reply card
Aeraspray Associated Ltd
Aerostyle Ltd
Aerox Ltd
Air Control Installations Ltd
Birflo Controls Ltd
Bivac Air Co Ltd
Burnett & Lewis Ltd
Burgess Products Co Ltd
Birfield Industries Ltd
Crosby Valve & Engineering Co Ltd
Davidson & Co Ltd
Dallow Lambert & Co Ltd
Doulton Industrial Porcelains Ltd
Edwards High Vacuum Ltd
Exactor Ltd
Fairey Aviation Co Ltd, The
Filter Co Ltd, The B & H
Gallenkamp & Co Ltd, A
Globe Pneumatic Engineering Co Ltd
Harris Engineering Co Ltd
Heather Filters Ltd
HEC Compressors & Engines Ltd
Honeywell Controls Ltd
Hymatic Engineering Co Ltd, The
Incandescent Heat Co Ltd
Intermit Ltd
Keith Blackman Ltd
Lacy-Hulbert & Co Ltd
Mancuna Engineering Ltd
Matthews & Yates Ltd
Norgren Ltd, C. A
Ozonaire Engineering Co Ltd
South London Electrical Equipment Co Ltd
Standard & Pochin Bros Ltd
Stillite Products Ltd
Stream-Line Filters Ltd
Sturtevant Engineering Co Ltd
Sunvic Controls Ltd
Supervents Ltd
Taylor Controls Ltd
Telektron (GB) Ltd
Teddington Aircraft Controls Ltd
Tilghman's Ltd
Townson & Mercer Ltd
Vokes Ltd
Western Detail Mfrs Ltd
Williams & James (Engineers) Ltd
Wykeham & Co Ltd, W

★ *For further details circle on card facing page A60*

Filters—electrical (wave & frequency)

★ Circle No 105 on reply card

Airtech Ltd
Andec Ltd
Aveley Electric Ltd
Belling & Lee Ltd
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
English Electric Co Ltd, The
General Electric Co Ltd, The
Livingston Laboratories Ltd
Microcell Electronics
Mullard Equipment Ltd
Plessey Co Ltd, The
Rank Cintel Ltd
Research & Control Instruments Ltd
Standard Telephones & Cables Ltd
Salford Electrical Instruments Ltd
Turner Electrical Instruments Ltd, Ernest
Wykeham & Co Ltd, W

Filters—liquid

★ Circle No 106 on reply card

Aerox Ltd
APV Co Ltd
Ashworth & Parker Ltd
Auto-Kleen Strainers Ltd
Birfield Industries Ltd
British Filters Ltd
Boby & Co Ltd, William
British Steam Specialities Ltd
Candy Filter Co Ltd, The
Danfoss Mfg Co
Davey, Paxman & Co Ltd
Doulton Industrial Porcelains Ltd
Dowty Equipment Ltd
Endecotts (Filters) Ltd
Fairey Aviation Co Ltd, The
Filter Co Ltd, The E. & H
Firth Cleveland Instruments Ltd
Glenfield & Kennedy Ltd
Heat Transfer Ltd
HML (Engineering) Ltd
Innes & Co (Darlington) Ltd
Liquid Systems Ltd
Madan & Co Ltd, Charles S
Marston Excelsior Ltd
Nuclear Engineering Ltd
Plenty & Son Ltd
Pulsometer Engineering Co Ltd, The
Simmonds Aerocessories Ltd
Short Bros & Harland Ltd
Stein Atkinson Vickers Hydraulics
Telektron (GB) Ltd
Thompson-Kennicott Ltd, John

Filters—interference

★ Circle No 107 on reply card

Belling & Lee Ltd
Dubilier Condenser Co (1925) Ltd
Microcell Electronics
Mullard Ltd
Plessey Co Ltd, The

Filters—optical

★ Circle No 108 on reply card

Baker of Holborn Ltd, C
Barr & Stroud Ltd
Bausch & Lomb Optical Co Ltd
Beck Ltd, R. & J
British Optical Lens Co
Chance-Pilkington Optical Works
Dallmeyer Ltd, J. H
Electronic Machine Co Ltd
Griffin & George Ltd
Hearson & Co Ltd, Charles
Hilger & Watts Ltd
Kelvin & Hughes Ltd
Leech (Rochester) Ltd
Optical Works Ltd
Ottway & Co Ltd, W
Pullin & Co Ltd, R. B
United Kingdom Optical Co Ltd
Watson & Sons Ltd, W
Wray (Optical Works) Ltd

Flame failure equipment

★ Circle No 109 on reply card

Bailey Meters & Controls Ltd
Black Automatic Controls Ltd
British Thomson-Houston Co Ltd, The
Cass & Phillip Ltd
Danfoss Mfg Co
De La Rue & Co Ltd, Thomas (Potterton Division)
Elcontrol Ltd
Electronic Switchgear (London) Ltd
Ether Ltd
Fireye Controls Co Ltd
Honeywell Controls Ltd
KDG Instruments Ltd
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Magnetic Controls Ltd
Peri Controls Ltd
Radiovisor Parent Ltd
Rheostatic Co Ltd, The
Sargrove Electronics Ltd
Sauter Controls Ltd
Stonebridge Electrical Co Ltd, The
Teddington Aircraft Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd

Flexible couplings

★ Circle No 110 on reply card

Avery-Hardoll Ltd (Self-sealing)
Avica Equipment Ltd
Avimo Ltd
Birfield Industries Ltd
British Ermeto Corporation Ltd
British Thomson-Houston Co Ltd, The
BTR Industries Ltd
Conveyancer Fork Trucks Ltd
Clayton-Wright Ltd, Howard
Exactor Ltd (Self-sealing)
High-Pressure Components Ltd
Metalastik Ltd
Power Auxiliaries Ltd
Rollason Aerocessories Ltd
Ross, Courtenay & Co Ltd
Ryder & Co (Manchester) Ltd, Thomas
Silentbloc Ltd
Simplifix Couplings Ltd
Spenborough Engineering Co Ltd
Slingsby & Co Ltd, Walter
Taylor Controls Ltd
Wade Couplings Ltd
Whittaker, Hall & Co (1929) Ltd

Flow controllers, indicators and recorders

★ Circle No 111 on reply card

Airflow Developments Ltd
Alto Instruments (Great Britain) Ltd
Appleby & Ireland Ltd
Associated Automation Ltd
Avery-Hardoll Ltd
Bailey Meters & Controls Ltd
Birfield Industries Ltd
B & K Laboratories Ltd
Black Automatic Controls Ltd
Bristol's Instrument Co Ltd
British Arca Regulators Ltd
Cheltenham Auto Controls Ltd
Craven Electronics Ltd
DEV Engineering Co Ltd, The
Dunford & Elliott (Sheffield) Ltd
Edwards High Vacuum Ltd
Electroflo Meters Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Firth Cleveland Instruments Ltd
Fischer & Porter Ltd
Glosser Aircraft Co Ltd
Gordon & Co Ltd, James
Hall (Elec Engineers) Ltd, J. Edward
Headland Engineering Developments Ltd
High-Pressure Components Ltd
Honeywell Controls Ltd
Ionic Instruments (London) Ltd
Kandem Electrical Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Leeds Meter Co Ltd, The
Londex Ltd
Manchester Water Meter Co Ltd, The
Mechanical & Electronic Products (London) Ltd
Measurement Ltd
Nash & Thompson Ltd
Negretti & Zambra Ltd
Palmer Ltd, G. A. Stanley
Platon Ltd, G. A
Research & Control Instruments Ltd
Reavell & Co
Rheostatic Co Ltd, The
Rollason Aerocessories Ltd
Rotameter Mfg Co Ltd
Sargrove Electronics Ltd
Sauter Controls Ltd
Samson Controls (London) Ltd
Short & Mason Ltd
Simmonds Aerocessories Ltd
Sunvic Controls Ltd
Smiths Aircraft Instruments Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd
Tylors of London Ltd
Ultrasonics Ltd
Walker, Crosweller & Co Ltd
Western Mfg (Reading) Ltd
Williams & James (Engineers) Ltd
Wykeham & Co Ltd, W
Watford Electric & Mfg Co Ltd

Fluxmeters

★ Circle No 112 on reply card

British Thomson-Houston Co Ltd, The
Cambridge Instrument Co Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Kandem Electrical Ltd
Kent Ltd, George
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Pye & Co Ltd, W. G
Salford Electrical Instruments Ltd

Frequency changers

★ Circle No 113 on reply card

Craven Electronics Ltd
Electric Construction Co Ltd, The
Electro Dynamic Construction Co Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Laurence, Scott & Electromotors Ltd
Lancashire Dynamo & Crypto Ltd
Lion Electronic Developments Ltd
JV Radio & Television Ltd
Plessey Co Ltd, The
Racal Engineering Ltd
Siemens Edison Swan Ltd
Telefusion Engineering Ltd
Thompson Ltd, J. Langham
Vernons Industries Ltd
Winston Electronics Ltd

Frequency controllers

★ Circle No 114 on reply card

Aveley Electric Ltd
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
Electro Dynamic Construction Co Ltd
Everett, Edgcumbe & Co Ltd
General Electric Co Ltd, The
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
JV Radio & Television Ltd
Honeywell Controls Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Salford Electrical Instruments Ltd
Sanders (Electronics) Ltd, W. H
Parkinson & Cowan Instruments
Solartron Electronic Group Ltd, The
Taylor Controls Ltd
Vernons Industries Ltd

Frequency response meters

★ Circle No 115 on reply card

Airmec Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
British Physical Laboratories
British Thomson-Houston Co Ltd
Dawe Instruments Ltd
Ekco Electronics Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Everett, Edgcumbe & Co Ltd
Fairey Air Surveys Ltd
General Electric Co Ltd, The
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Labgear Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Microwave Instruments Ltd
Muirhead & Co Ltd
Nalder Bros & Thompson Ltd
Racal Engineering Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Sangamo Weston Ltd
Solartron Electronic Group
Telefusion Engineering Ltd
Venner Electronics Ltd
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd
Wykeham & Co Ltd, W

Galvanometers

★ Circle No 116 on reply card

Anders Electronics Ltd
Bailey Meters & Controls Ltd
Baird & Tatlock (London) Ltd
Baldwin Instrument Co Ltd
B & K Laboratories Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Crompton Parkinson Ltd
Cuthbert Ltd, Ralph
Doran Instrument Co Ltd
Elliott Bros (London) Ltd
Ether Ltd
Evans Electroselenium Ltd
Electrical Instrument Co (Hillingdon) Ltd, The
Farnell Instruments Ltd
Foster Instrument Co Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Industrial Pyrometer Co Ltd
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Measuring Instruments (Pullin) Ltd
Murex Ltd
New Electronic Products Ltd
Pye & Co Ltd, W. G
Record Electrical Co Ltd, The
Robinson & Partners Ltd, F. C
Salford Electrical Instruments Ltd

★ *For further details circle on card facing page A60*

Sangamo Weston Ltd
Savage & Parsons Ltd
Shandon Scientific Co Ltd
Siemens Edison Swan Ltd
Sullivan Ltd, H. W
Taylor Electrical Instruments Ltd
Turner Electrical Instruments Ltd, Ernest
Tinsley & Co Ltd, H
White Electrical Instrument Co Ltd
West Instrument Ltd

Gas analysers
★ Circle *No 117* on reply card
Associated Automation Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Camlab (Glass) Ltd
Combustion Instruments
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Engelhard Industries Ltd
Evershed & Vignoles Ltd
Foxboro-Yoxall Ltd
Glass Developments Ltd
Gordon & Co Ltd, James
Griffin & George Ltd
Hobson Ltd, H. M
Honeywell Controls Ltd
Infra-Red Development Co Ltd, The
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Measurement Ltd
Metropolitan-Vickers Electrical Co Ltd
Mine Safety Appliances Co Ltd
Perkin-Elmer A. G
Pye & Co Ltd, W. G
Rotameter Mfg Co Ltd
Shandon Scientific Co Ltd
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd
Towers & Co Ltd, J. W
Watford Electric & Mfg Co Ltd
Wykeham & Co Ltd, W

Gearing—precision
★ Circle *No 118* on reply card
Air Trainers Link Ltd
Appleby & Ireland Ltd
Angus & Co Ltd, George
Barr & Stroud Ltd
British Thomson-Houston Co Ltd, The
Brown Ltd, S. G
Carter Gears Ltd
Cass & Phillip Ltd
Davall Gear Co Ltd
Elliott Bros (London) Ltd
Ferraris (Clerkenwell) Ltd, Fred
Graseby Instruments Ltd
Laurence, Scott & Electromotors Ltd
Opperman Ltd, S. E
Plessey Co Ltd, The
Pringle & Sons (London) Ltd, Robert
Pullin & Co Ltd, R. B
Scientific & Projections Ltd
Spencer Components Ltd
Sterling Instrument Co Ltd
Sperry Gyroscope Co Ltd
Tufnol Ltd
Vactric (Control Equipment) Ltd
Western Mfg (Reading) Ltd

Generators—a.c
★ Circle *No 119* on reply card
Andec Ltd
Appleby & Ireland Ltd
British Brown-Boveri Ltd
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
Crompton Parkinson Ltd
Electric Construction Co Ltd, The
EMI Electronics Ltd
English Electric Co Ltd, The
Harland Engineering Co Ltd
Kelvin & Hughes Ltd
Lancashire Dynamo & Crypto Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Meadows Ltd, Henry
Metropolitan-Vickers Electrical Co Ltd
Parsons & Co Ltd, C. A
Research & Control Instruments Ltd
Sykes Ltd, Henry
Solartron Electronic Group Ltd, The
Vernon Industries Ltd
Whitetrade Ltd

Generators—d.c
★ Circle *No 120* on reply card
Allis-Chalmers (Great Britain) Ltd
Andec Ltd
British Brown-Boveri Ltd
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
Crompton Parkinson Ltd
Electric Construction Co Ltd, The
EMI Electronics Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Harland Engineering Co Ltd
Kelvin & Hughes Ltd
Lancashire Dynamo Electronic Products Ltd
Lancashire Dynamo & Crypto Ltd
Laurence, Scott & Electromotors Ltd
Metropolitan-Vickers Electrical Co Ltd
Parsons & Co Ltd, C. A
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Sykes Ltd, Henry
Vernons Industries Ltd
Whitetrade Ltd

Generators—noise
★ Circle *No 121* on reply card
B & K Laboratories Ltd
Dawe Instruments Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Servomex Controls Ltd

Generators—pulse
★ Circle *No 122* on reply card
Allied Electronics Ltd
B & K Laboratories Ltd
Bradley Ltd, G. & E
British Physical Laboratories
Cawkell Research & Electronics Ltd
Cossor Instruments Ltd
Dawe Instruments Ltd
Dowty Nucleonics Ltd
Dynatron Radio Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Ferranti Ltd
Fleming Radio (Developments) Ltd
General Electric Co Ltd, The
General Radiological Ltd
Isotope Developments Ltd
Kasama Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Microcell Electronics
Mullard Equipment Ltd
Metropolitan-Vickers Electrical Co Ltd
Nagard Ltd
Panax Equipment Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd

Generators—sweep
★ Circle *No 123* on reply card
B & K Laboratories Ltd
EMI Electronics Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Taylor Electrical Instruments Ltd

Generators—synchronous
★ Circle *No 124* on reply card
Andec Ltd
Appleby & Ireland Ltd
British Thomson-Houston Co Ltd, The
English Electric Co Ltd, The
Laurence, Scott & Electromotors Ltd
Metropolitan-Vickers Electrical Co Ltd
Vernons Industries Ltd

Generators—ultrasonic
★ Circle *No 125* on reply card
Baird & Tatlock (London) Ltd
B & K Laboratories Ltd
British Physical Laboratories
Cawkell Research & Electronics Ltd
Craven Electronics Ltd
General Radiological Ltd
Glass Developments Ltd
Kelvin & Hughes Ltd
Kerry's (Ultrasonics) Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Equipment Ltd
Redifon Ltd
Rivlin Instruments Ltd
Solartron Electronic Group Ltd, The
Ultrasonics Ltd

Generators—wave
★ Circle *No 126* on reply card
Allied Electronics Ltd
B & K Laboratories Ltd
Aveley Electric Ltd
British Physical Laboratories
Cawkell Research & Electronics Ltd
Dynatron Radio Ltd
EMI Electronics Ltd
Faraday Electronic Instruments Ltd
General Radiological Ltd
Glass Developments Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Microcell Electronics
Mullard Ltd
Nagard Ltd
Panax Equipment Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Taylor Electrical Instruments Ltd
Venner Electronics Ltd

Gyros—directional
★ Circle *No 127* on reply card
Brown Ltd, S. G
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Fairey Aviation Co Ltd, The
Ferranti Ltd
Kelvin & Hughes Ltd
Pullin & Co Ltd, R. B
Reid & Sigrist Ltd
Smiths Aircraft Instruments Ltd
Sperry Gyroscope Co Ltd
Test Equipment Ltd

Gyro—integrators
★ Circle *No 128* on reply card
English Electric Co Ltd, The
Pullin & Co Ltd, R. B

Gyro—pilots (aircraft and marine)
★ Circle *No 129* on reply card
Brown Ltd, S. G
Elliott Bros (London) Ltd
Pullin & Co Ltd,, R. B
Reid & Sigrist Ltd
Smiths Aircraft Instruments Ltd
Sperry Gyroscope Co Ltd

Gyro—stabilizers
★ Circle *No 130* on reply card
Brown Ltd, S. G
Elliott Bros (London) Ltd
Muirhead & Co Ltd
Pullin & Co Ltd, R. B
Reid & Sigrist Ltd
Sperry Gyroscope Co Ltd

Gyros—vertical and rate
★ Circle *No 131* on reply card
Brown Ltd, S. G
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Fairey Aviation Co Ltd, The
Kelvin & Hughes Ltd
Ketay Ltd
Muirhead & Co Ltd
Pullin & Co Ltd, R. B
Reid & Sigrist Ltd
Sperry Gyroscope Co Ltd
Test Equipment Ltd

Harmonic analysers
★ Circle *No 132* on reply card
Airmec Ltd
Air Trainers Link Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Craven Electronics Ltd
Dawe Instruments Ltd
Emeco Electronics Ltd
EMI Electronics Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Muirhead & Co Ltd
Robinson & Partners Ltd, F. C
Servomex Controls Ltd
Siemens Edison Swan Ltd
Solartron Electronic Group Ltd
Stanley & Co Ltd, W. F
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd

Heat flow indicators and recorders
★ Circle *No 133* on reply card
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Kent Ltd, George
Integra, Leeds & Northrup Ltd
Joyce, Loebl & Co Ltd

Humidity indicators, recorders and controllers
★ Circle *No 134* on reply card
Appleby & Ireland Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Arca Regulators Ltd
Cambridge Instrument Co Ltd
Drayton Regulator & Instrument Co Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Fielden Electronics Ltd
Foxboro-Yoxall Ltd
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Infra-Red Developments Ltd
Kandem Electrical Ltd
Kingston Control Systems Ltd
Lock & Co Ltd, A. M
Lancashire Dynamo Electronic Products Ltd
Negretti & Zambra Ltd
PAM Ltd
Research & Control Instruments Ltd

★ *For further details circle on card facing page A60*

Reynolds & Branson Ltd
Sargrove Electronics Ltd
Sauter Controls Ltd
Shaw Moisture Meters
Short & Mason Ltd
Standard Telephones & Cables Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Tintometer Co Ltd
Thermocontrol Installations Co Ltd
Watford Electric & Mfg Co Ltd
Zeal Ltd, G. H

Ignitrons

★ Circle *No 135* on reply card

British Thomson-Houston Co Ltd, The
English Electric Co Ltd, The
English Electric Valve Co Ltd
Metropolitan-Vickers Electrical Co Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H

Illumination controllers

★ Circle *No 136* on reply card

Allied Electronics Ltd
Cirrex Communications Equipment (1948) Ltd
Elcontrol Ltd
Electronic Machine Co
Electronic Switchgear (London) Ltd
Elliott Bros (London) Ltd
Evans Electroselenium Ltd
General Electric Co Ltd
Hall (Electrical Engineers) Ltd, J. Edward
Instruments & Controls Ltd
Lock & Co Ltd, A. M
Metropolitan Vickers & Co Ltd
Parkinson & Cowan Instruments
Radiovisor Parent, Ltd
Salford Electrical Instruments Ltd
Sargrove Electronics Ltd

Inductance measuring equipment

★ Circle *No 137* on reply card

Advance Components Ltd
Aveley Electric Ltd
Avo Ltd
B & K Laboratories Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Hatfield Instruments Ltd
Integra, Leeds & Northrup Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Measuring Instruments (Pullin) Ltd
Muirhead & Co Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd
Wykeham & Co Ltd, W

Inductors

Airtech Ltd

★ Circle *No 138* on reply card

Aveley Electric Ltd
Belling & Lee Ltd
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
Correx Communications Equipment (1948) Ltd
Dawe Instruments Ltd
Elliott Bros (London) Ltd
Gardners Radio Ltd
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Measuring Instruments (Pullin) Ltd
Mullard Ltd
Robinson & Partners Ltd, F. C
Sullivan Ltd, H. W
Tinsley & Co Ltd, H

Industrial & process control systems

★ Circle *No 139* on reply card

Airmec Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Black Automatic Controls Ltd
British Federal Welder & Machine Co Ltd
British Rototherm Co Ltd
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
Burndept Ltd
Cass & Phillip Ltd
Dunford & Elliott (Sheffield) Ltd
Ekco Electronics Ltd
Electrical Remote Control Co Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ether Ltd
Electronic Machine Co Ltd
Ericsson Telephones Ltd
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
Fairey Aviation Co Ltd, The
Fielden Electronics Ltd
Fischer & Porter Ltd
Fisher Governor Co Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Hendrey Relays Ltd
Honeywell Controls Ltd
Hunt & Mitton Ltd
Hunting Aircraft Ltd
Industrial Pyrometer Co Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Lock & Co Ltd, A. M
Londex Ltd
Lucas (Electrical) Ltd, Joseph
Metropolitan-Vickers Electrical Co Ltd
Mead & Phasey Ltd
Measurement Ltd
Microcell Electronics
Mullard Ltd
Nagard Ltd
Negretti & Zambra Ltd
Perl Controls Ltd
Process Control Gear Ltd
Pye & Co Ltd, W. G
Racal Engineering Ltd
Radiovisor Parent Ltd
Research & Control Instruments Ltd
Rheostatic Co Ltd, The
Robinson & Partners Ltd, F. C
Rotameter Mfg Co Ltd
Samson Controls (London) Ltd
Sanders (Electronics) Ltd, W. H
Saunders-Roe Ltd
Sauter Controls Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd
Square D Ltd
Sunvic Controls Ltd
South London Electrical Equipment Co Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Telektron (GB) Ltd
Teledictor Ltd
Thermocontrol Installations Co Ltd
Tylors of London Ltd
Venner Electronics Ltd
Watford Electric & Mfg Co Ltd
Wayne Kerr Laboratories Ltd
Western Mfg (Reading) Ltd
WS Electronics (Production) Ltd
Wykeham & Co Ltd, W

Infra-red detectors

★ Circle *No 140* on reply card

Andec Ltd
British Thomson-Houston Co Ltd, The
EMI Ectronics Ltd
Farnell Instruments Ltd
Hilger & Watts Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Mine Safety Appliances Co Ltd
Mullard Ltd
Perkin-Elmer, A. G
Plessey Co Ltd, The
Radiovisor Parent Ltd
Technical Ceramics Ltd
Unicam Instruments Ltd

Integrators

★ Circle *No 141* on reply card

Air Trainers Link Ltd
Associated Automation Ltd
B & K Laboratories Ltd
Counting Instruments Ltd
Dunford & Elliott (Sheffield) Ltd
Electro Methods Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evans Electroselenium Ltd
Evershed & Vignoles Ltd
Fischer & Porter Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Plessey Co Ltd, The
Solartron Electronic Group Ltd, The
Short Bros & Harland Ltd
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
Stanley & Co Ltd, W. F
Taylor Controls Ltd
Telephone Rentals Ltd
Thompson Instrument Co Ltd, John
Technical Sales

Inverters

★ Circle *No 142* on reply card

Appleby & Ireland Ltd
British Thomson-Houston Co Ltd, The
English Electric Co Ltd, The
Livingston Laboratories Ltd
Mullard Ltd
Plessey Co Ltd, The
Vernons Industries Ltd

Isotopes

★ Circle *No 143* on reply card

Baldwin Instrument Co Ltd
Isotope Developments Ltd
Lock & Co Ltd, A. M
Radiochemical Centre
Research & Control Instruments Ltd
Solus-Schall Ltd
20th Century Electronics Ltd

Klystrons

★ Circle *No 144* on reply card

B & K Laboratories Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Valve Co Ltd
Ferranti Ltd
General Electric Co Ltd, The
Livingston Laboratories Ltd
Mullard Ltd
Sanders (Electronics) Ltd, W. H
Standard Telephones & Cables Ltd

Leak detectors

★ Circle *No 145* on reply card

Appleby & Ireland Ltd
Associated Automation Ltd
Baird & Tatlock (London) Ltd
British Thomson-Houston Co Ltd, The
Camlab (Glass) Ltd
Edwards High Vacuum Ltd
Elliott Bros (London) Ltd
Ether Ltd
Ferranti Ltd
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
Griffin & George Ltd
Infra-Red Development Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Nash & Thompson Ltd
Pulsometer Engineering Co Ltd
Pye & Co Ltd, W. G
Short & Mason Ltd
Test Equipment Ltd
20th Century Electronics Ltd

Level indicators, controllers and recorders

★ Circle *No 146* on reply card

Airmec Ltd
Appleby & Ireland Ltd
Associated Automation Ltd
Avery-Hardoll Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
Bristol's Instrument Co Ltd
British Thomson-Houston Co Ltd, The
Crosby Valve & Engineering Co Ltd
Correx Communications Equipment (1948) Ltd
Danfoss Mfg Co
Dunford & Elliott (Sheffield) Ltd
Elcontrol Ltd
Electronic Machine Co Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Fischer & Porter Ltd
Firth Cleveland Instruments Ltd
Gordon & Co Ltd, James
Hall (Elec Engineers) Ltd, J. Edward
Honeywell Controls Ltd
Hunting Aircraft Ltd
Hunt & Mitton Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
KDG Instruments Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Londex Ltd
Measurement Ltd
Negretti & Zambra Ltd
Radiovisor Parent Ltd
Research & Control Instruments Ltd
Rotameter Mfg Co Ltd
Salford Electrical Instruments Ltd
Samson Controls (London) Ltd
Sauter Controls Ltd
Simmonds Aerocessories Ltd
Smiths Industrial Instruments Division
Sunvic Controls Ltd
Taylor Controls Ltd
Telefusion Engineering Ltd
Teddington Industrial Equipment Ltd
Thompson Ltd, J. Langham
Trist & Co Ltd, Ronald
Wykeham & Co Ltd, W

Load cells

★ Circle *No 147* on reply card

Appleby & Ireland Ltd
B & K Laboratories Ltd
Davy & United Engineering Co Ltd
Elliott Bros (London) Ltd
Gloster Aircraft Co Ltd
Research & Control Instruments Ltd
Short & Mason Ltd
Taylor Controls Ltd
Thompson Ltd, J. Langham

Load indicators, controllers and recorders

★ Circle *No 148* on reply card

Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Correx Communications Equipment (1948) Ltd

★ *For further details circle on card facing page A60*

Davy & United Engineering Co Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Fielden Electronics Ltd
Hirst Electronic Ltd
Integra, Leeds & Northrup Ltd
Lancashire Dynamo Electronic Products Ltd
Research & Control Instruments Ltd
Taylor Controls Ltd
Thompson Ltd, J. Langham

Machine tool control systems
★ Circle *No 149* on reply card
Airmec Ltd
Black Automatic Controls Ltd
British Federal Welder & Machine Co Ltd
British Thomson-Houston Co Ltd, The
Burndept Ltd
Conveyancer Fork Trucks Ltd
Creed & Co Ltd
Dunford & Elliott (Sheffield) Ltd
Ekco Electronics Ltd
EMI Electronics Ltd
Electronic Machine Co Ltd
Ericsson Telephones Ltd
Fairey Aviation Co Ltd, The
Ferranti Ltd
Gloster Aircraft Co Ltd
Hilger & Watts Ltd
Industrial Technics (Southampton) Ltd
Klöckner-Moeller England Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Equipment Ltd
Nickols Automatics Ltd
Plessey Co Ltd, The
Radiovisor Parent Ltd
Reilly Engineering Ltd
Robinson & Partners Ltd, F. C
Solartron Electronic Group Ltd, The
Speck Ltd, Robert
Sperry Gyroscope Co Ltd
Teddington Industrial Equipment Ltd
WS Electronics (Production) Ltd
Watford Electric & Mfg Co Ltd

Magnetic tape recorders
★ Circle *No 150* on reply card
Andec Ltd
Baird Television (Hartley Baird) Ltd
B & K Laboratories Ltd
Boosey & Hawkes (Electronics Division) Ltd
Bradmatic Ltd
Burne-Jones & Co Ltd
CJR Electrical & Electronic Development Ltd
Emeco Electronics Co
EMI Electronics Ltd
Epsylon Sound Accessories Ltd
Griffin & George Ltd
GB—Kalee Ltd
Grundig (Great Britain) Ltd
Holiday & Hemmerdinger Ltd
Instruments & Controls Ltd
Kelvin & Hughes Ltd
Lee Products (Great Britain) Ltd
Livingston Laboratories Ltd
MSS Recording Co Ltd
Marconi Instruments Ltd
Mervyn Instruments
Phillips & Bonson Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Salford Electrical Instruments Ltd
Savage & Parsons Ltd
Shipton & Co Ltd, E
Solartron Electronic Group Ltd, The
Tape Recorders ((Electronics) Ltd
Walter Instruments Ltd
Winston Electronics Ltd

Magnetic recording tape
★ Circle *No 151* on reply card
B & K Laboratories Ltd
EMI Electronics Ltd
GB—Kalee Ltd
General Electric Co Ltd, The
EMI Electronics Ltd
Holiday & Hemmerdinger Ltd
Kodak Ltd
Lee Products (Great Britain) Ltd
Livingston Laboratories Ltd
Magnetic Coatings Ltd
MSS Recording Co Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Salford Electrical Instruments Ltd
Tape Recorders (Electronics) Ltd
Walter Instruments Ltd

Magnetic brakes
★ Circle *No 152* on reply card
Allen West & Co Ltd
British Thomson-Houston Co Ltd, The
General Electric Co Ltd, The
Heenan & Froude Ltd
Igranic Electric Co Ltd
JD Electronics (Birmingham) Ltd
Magnetic Equipment Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
MTE Control Gear Ltd
Rapid Magnetic Machines Ltd
Westinghouse Brake & Signal Co Ltd
Westool Ltd

Magnetic storage devices
★ Circle *No 153* on reply card
Automatic Telephone & Electric Co Ltd
British Tabulating Machine Co Ltd, The
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ferranti Ltd
Metropolitan-Vickers Electrical Co Ltd
Plessey Co Ltd, The
Rank Cintel Ltd
Reid & Sigrist Ltd
Sperry Gyroscope Co Ltd

Magslips
★ Circle *No 154* on reply card
Appleby & Ireland Ltd
British Thomson-Houston Co Ltd, The
General Electric Co Ltd, The
Ketay Ltd
Laurence, Scott & Electromotors Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Mullard Ltd
Sperry Gyroscope Co Ltd
Thompson Instrument Co Ltd, John

Marine instruments
★ Circle *No 155* on reply card
Barr & Stroud Ltd
Bloctube Controls Ltd
Dobbie McInnes Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Laurence, Scott & Electromotors Ltd
Millett, Levens (Instruments & Engineering) Ltd
Ottway & Co Ltd, W
Parkinson & Cowan Instruments
Pullin & Co Ltd, R. B
Record Electrical Co Ltd, The
Smiths Industrial Instruments Division
Sperry Gyroscope Co Ltd
Stanley & Co Ltd, W. F
Teleflex Products Ltd

Master clocks
★ Circle *No 156* on reply card
Aveley Electric Ltd
Cass & Phillip Ltd
Gent & Co Ltd
Instruments & Controls Ltd
JV Radio & Television Ltd
Lancashire Dynamo Electronic Products Ltd

Miniature instrumentation
★ Circle *No 157* on reply card
Anders Electronics Ltd
Appleby & Ireland Ltd
Ardente Acoustic Laboratories Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Physical Laboratories
Brown Ltd, S. G
Cass & Phillip Ltd
Crompton Parkinson Ltd
Electroflo Meters Co Ltd
Electro Mechanisms Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Honeywell Controls Ltd
Instruments & Controls Ltd
Kandem Electrical Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Nalder Bros & Thompson Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Sangamo Weston Ltd
Solartron Electronic Group Ltd, The
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Taylor Controls Ltd
Taylor Electrical Instruments Ltd
Turner Electrical Instruments Ltd, Ernest
Venner Electronics Ltd
WS Electronics (Production) Ltd

Modulation indicators
★ Circle *No 158* on reply card
Airmec Ltd
Aveley Electric Ltd
Hatfield Instruments Ltd
Livingston Laboratories Ltd
Measuring Instruments (Pullin) Ltd
Solartron Electronic Group Ltd, The
Turner Electrical Instruments Ltd, Ernest

Modulators
★ Circle *No 159* on reply card
Aveley Electric Ltd
English Electric Co Ltd, The
Lion Electronic Developments Ltd
Solartron Electronic Group Ltd, The

Motors—servo
★ Circle *No 160* on reply card
Andec Ltd
ASEA Electric Ltd
British Thomson-Houston Co Ltd, The
Brook Motors Ltd
Brown Ltd, S. G.
Crompton Parkinson Ltd
Electro Dynamic Construction Co Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Fractional H.P. Motors Ltd
Fuller Electrical & Mfg Co Ltd
General Electric Co Ltd, The
General Motors Ltd (Frigidaire Division)
Globe Pneumatic Engineering Co Ltd
Gordon & Co Ltd, James
Graseby Instruments Ltd
Higgs Motors Ltd
Hillman Electric Motors Ltd
Honeywell Controls Ltd
Hoover Ltd
Jones & Stevens Ltd
Kingston Control Systems Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Ketay Ltd
Klaxon Ltd
Laurence, Scott & Electromotors Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
McKellard Automation Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Pell Control Ltd, Oliver
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Sangamo Weston Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instruments Division
Sperry Gyroscope Co Ltd
Stonebridge Electrical Co Ltd, The
Thermocontrol Installations Co Ltd
Telektron GB) Ltd
Townson & Mercer Ltd
Vernons Industries Ltd

Motors (torque)—electric
★ Circle *No 161* on reply card
Brook Motors Ltd
Brown Ltd, S. G
Brush Electrical Engineering Co Ltd
Crompton Parkinson Ltd
Electric Construction Co Ltd, The
Elliott Bros (London) Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Hillman Electric Motors Ltd
Honeywell Controls Ltd
Kelvin & Hughes Ltd
Ketay Ltd
Kinston Control Systems Ltd
Klaxon Ltd
Metropolitan-Vickers Electrical Co Ltd
Motor Electrics Co
Muirhead & Co Ltd
Pullin & Co Ltd, R. B
Rheostatic Co Ltd, The
Sauter Controls Ltd
Sperry Gyroscope Co Ltd
Teddington Industrial Equipment Ltd
Test Equipment Ltd
Thermocontrol Installations Co Ltd
Vernons Industries Ltd

Motors (torque)—hydraulic
★ Circle *No 162* on reply card
Automotive Products Co Ltd (Lockheed Hydraulic Division)
Dowty Hydraulic Units Ltd
Elliott Bros (London) Ltd
Fawcett-Finney Ltd
Fraser & Co Ltd, Andrew
Gordon & Co Ltd, James
Hamworthy Engineering Ltd
Hydraulics & Pneumatics Ltd
Integral Ltd
Keelavite Rotary Pumps & Motors Ltd
Leeds Engineering & Hydraulic Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Sauter Controls Ltd
Spenborough Engineering Co Ltd
Sperry Gyroscope Co Ltd
Stein Atkinson Vickers Hydraulics Ltd
Test Equipment Ltd
Vickers-Armstrongs (Engineers) Ltd

Motors (torque)—pneumatic
★ Circle *No 163* on reply card
Bailey Meters & Controls Ltd
Consolidated Pneumatic Tool Co Ltd
Fraser & Co Ltd, Andrew
Globe Pneumatic Engineering Co Ltd
Gordon & Co Ltd, James
Hydraulics & Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Spenborough Engineering Co Ltd
Telektron (GB) Ltd

★ *For further details circle on card facing page A60*

Test Equipment Ltd
Vickers Armstrongs (Engineers) Ltd

Non-destructive testing equipment
★ Circle *No 164* on reply card
B & K Laboratories Ltd
Dawe Instruments Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
General Radiological Ltd
Glass Developments Ltd
Isotope Developments Ltd
Kelvin & Hughes Ltd
Marconi Instruments Ltd
Microcell Electronics
Nash & Thompson Ltd
Research & Control Instruments Ltd
Solatron Electronic Group Ltd, The
Solus-Schall Ltd
Sperry Gyroscope Co Ltd
Teledictor Ltd
Western Mfg (Reading) Ltd

Nuclear reactor control systems
★ Circle *No 165* on reply card
Appleby & Ireland Ltd
Ardleigh Engineering Ltd
Arens Controls Ltd
Bailey Meters & Controls Ltd
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
Burndept Ltd
Dowty Nucleonics Ltd
Dynatron Radio Ltd
Ekco Electronics Ltd
Electro-Hydraulics Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
English Electric Co Ltd, The
Ether Ltd
Evershed & Vignoles Ltd
Fairey Aviation Co Ltd, The
Fielden Electronics Ltd
General Electric Co Ltd, The
General Radiological Ltd
Gordon & Co Ltd, James
Hall & Cox Ltd, Matthew
Hawker Siddeley Nuclear Power Co Ltd
Hobson Ltd, H. M
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
Kent Ltd, George
Ketay Ltd
Labgear Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Mullard Equipment Ltd
NGN Electrical Ltd
Plessey Nucleonics Ltd
Pye & Co Ltd, W. G
Ramsey Engineering Co Ltd
Research & Control Instruments Ltd
Reyrolle & Co Ltd, A
Rolls-Royce Ltd
Salford Electrical Instruments Ltd
Samson Controls (London) Ltd
Short Bros & Harland Ltd
Sperry Gyroscope Co Ltd
Solartron Electronic Group Ltd, The
Sunvic Controls Ltd
Teleflex Products Ltd
Telektron (GB) Ltd
Thermocontrol Installations Co Ltd

Nuclear reactor instrumentation
★ Circle *No 166* on reply card
Appleby & Ireland Ltd
Accurate Recording Instrument Co, The
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Burndept Ltd
Dynatron Radio Ltd
Ekco Electronics Ltd
Electro Mechanisms Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Ether Ltd
Evershed & Vignoles Ltd
Fairey Aviation Co Ltd, The
Fielden Electronics Ltd
Fischer & Porter Ltd
Fleming Radio (Developments) Ltd
Foxboro-Yoxall Ltd
General Electric Co Ltd, The
General Radiological Ltd
Gloster Aircraft Co Ltd
Hawker Siddeley Nuclear Power Co Ltd
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
Kent Ltd, George
Lintronic Ltd
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Equipment Ltd
Plessey Nucleonics Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Savage & Parsons Ltd
Salford Electrical Instruments Ltd
Short & Mason Ltd
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd
Sunvic Controls Ltd
Teddington Industrial Equipment Ltd

Nucleonic apparatus
★ Circle *No 167* on reply card
Airmec Ltd
Avo Ltd
B & K Laboratories Ltd
Dynatron Radio Ltd
Ekco Electronics Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Fleming Radio (Developments) Ltd
General Electric Co Ltd, The
General Radiological Ltd
Hilger & Watts Ltd
Integra, Leeds & Northrup Ltd
Isotope Developments Ltd
Kent Ltd, George
Labgear Ltd
Lintronic Ltd
Lock & Co Ltd, A. M
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Morgan Crucible Co Ltd, The
Mullard Equipment Ltd
Plessey Nucleonics Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Savage & Parsons Ltd
Solartron Electronic Group Ltd, The
"Solus" Electronic Tubes Ltd, The
Sperry Gyroscope Co Ltd
Winston Electronics Ltd

Orifice plates
★ Circle *No 168* on reply card
Airflow Developments Ltd
Alto Instruments (Great Britain) Ltd
Bailey Meters & Controls Ltd
Bristol's Instrument Co Ltd
British Pitometer Co Ltd
Cussons Ltd, G
Electroflo Meters Co Ltd
Foxboro-Yoxall Ltd
Kent Ltd, George
Livingston Laboratories Ltd
Negretti & Zambra Ltd
Rotameter Mfg Co Ltd
Stonebridge Electrical Co Ltd
Taylor Controls Ltd
Thompson Instrument Co Ltd, John
Tylors of London Ltd

Oscillators—a.f
★ Circle *No 169* on reply card
Advance Components Ltd
Airmec Ltd
Allied Electronics Ltd
Amos (Electronics) Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Cawkell Research & Electronics Ltd
Craven Electronics Ltd
Dawe Instruments Ltd
Emeco Electronics Co
EMI Electronics Ltd
Farnell Instruments Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
Goodmans Industries Ltd
Griffin & George Ltd
Hatfield Instruments Ltd
Hifi Ltd
Holiday & Hemmerdinger Ltd
Kardem Electrical Ltd
Kasama Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Leland Instruments Ltd
Lion Electronic Developments Ltd
Marconi Instruments Ltd
Muirhead & Co Ltd
Nash & Thompson Ltd
Plessey Co Ltd, The
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Salford Electrical Instruments Ltd
Savage Ltd, W. Bryan
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Sullivan Ltd, H. W
Taylor Electrical Instruments Ltd
Tinsley & Co Ltd, H
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Oscillators—microwave
★ Circle *No 170* on reply card
Allied Electronics Ltd
Aveley Electric Ltd
Cambridge Instrument Co Ltd
English Electric Co Ltd, The
Farnell Instruments Ltd
General Electric Co Ltd, The
Holiday & Hemmerdinger Ltd
Kasama Electronics Ltd
Leland Instruments Ltd
Lock & Co Ltd, A. M
Livingston Laboratories Ltd
Marconi Instruments Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Rank Cintel Ltd
Sanders (Electronics) Ltd, W. H
Salford Electrical Instruments Ltd
Solartron Electronic Group Ltd, The
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Oscillators—r.f
★ Circle *No 171* on reply card
Advance Components Ltd
Airmec Ltd
Amos (Electronics) Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
British Physical Laboratories
Craven Electronics Ltd
Dawe Instruments Ltd
Emeco Electronics Co
English Electric Co Ltd, The
Farnell Instruments Ltd
Hatfield Instruments Ltd
Hifi Ltd
Kandem Electrical Ltd
Kasama Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Leland Instruments Ltd
Mullard Ltd
Marconi Instruments Ltd
Nash & Thompson Ltd
Plessey Co Ltd, The
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Sullivan Ltd, H. W
Taylor Electrical Instruments Ltd
Wayne Kerr Laboratories Ltd

Oscillators—ultrasonic
★ Circle *No 172* on reply card
B & K Laboratories Ltd
British Physical Laboratories
Cambridge Instrument Co Ltd
Cawkell Research & Electronics Ltd
Farnell Instruments Ltd
Glass Developments Ltd
Kerry's (Ultrasonics) Ltd
Livingston Laboratories Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Savage Ltd, W. Bryan
Solartron Electronic Group Ltd

Oscillographs
★ Circle *No 173* on reply card
Airmec Ltd
Allied Electronics Ltd
Amos (Electronics) Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Boulton Paul Aircraft Ltd
BPL (Instruments) Ltd
British Brown-Boveri Ltd
Cambridge Instrument Co Ltd
Cawkell Research & Electronics Ltd
Cossor Instruments Ltd
EMI Electronics Ltd
Faraday Electronic Instruments Ltd
Farnell Instruments Ltd
Ferranti Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
Griffin & George Ltd
Hatfield Instruments Ltd
Honeywell Controls Ltd
Kasama Electronics Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Lyons Ltd, Claude
Marconi Instruments Ltd
McKellan Automation Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Equipment Ltd
Nagard Ltd
New Electronic Products Ltd
Parkinson & Cowan Instruments
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Savage & Parsons Ltd
Solartron Electronic Group Ltd, The

★ *For further details circle on card facing page A60*

Southern Instruments Computer Division
Standard Telephones & Cables Ltd
Taylor Electrical Instruments Ltd
20th Century Electronics Ltd
Wykeham & Co Ltd, W

Oscilloscopes—cathode ray
★ Circle *No 174* on reply card
Airmec Ltd
Allied Electronics Ltd
Aveley Electric Ltd
British Physical Laboratories
Cawkell Research & Electronics Ltd
Cossor Instruments Ltd
Craven Electronics Ltd
Ekco Electronics Ltd
Emeco Electronics Co
EMI Electronics Ltd
Faraday Electronic Instruments Ltd
Farnell Instruments Ltd
Ferranti Ltd
Furzehill Laboratories Ltd
Griffin & George Ltd
Hatfield Instruments Ltd
General Electric Co Ltd, The
Joyce, Loebl & Co Ltd
JV Radio & Television Ltd
Kandem Electrical Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Lion Electronic Developments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Leland Instruments Ltd
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Equipment Ltd
Nagard Ltd
New Electronic Products Ltd
Newport Instruments (Scientific & Mobile) Ltd
Panax Equipment Ltd
Parkinson & Cowan Instruments
Plessey Co Ltd, The, (High Speed)
Rank Cintel Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Saunders-Roe Ltd
Robinson & Partners Ltd, F. C
Sargrove Electronics Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Stonebridge Electrical Co Ltd, The
Taylor Electrical Instruments Ltd
20th Century Electronics Ltd
Wykeham & Co Ltd, W

pH indicators, controllers and recorders
★ Circle *No 175* on reply card
Analytical Measurements Ltd
Baird & Tatlock (London) Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Doran Instrument Co Ltd
Electroflo Meters Co Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Farnell Instruments Ltd
Foxboro-Yoxall Ltd
Fielden Electronics Ltd
Griffin & George Ltd
Hearson & Co Ltd, Charles
Honeywell Controls Ltd
Ionic Instruments (London) Ltd
Integra, Leeds & Northrup Ltd
Kent Ltd, George
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Robinson & Partners Ltd, F. C
Research & Control Instruments Ltd
Tintometer Co Ltd
Thermocontrol Installations Co Ltd
Towers & Co Ltd, J. W
Turner Electrical Instruments Ltd, Ernest
Wykeham & Co Ltd, W

Phase angle indicators
★ Circle *No 176* on reply card
Airmec Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Electrical Instrument Co (Hillington) Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Fairey Airsurveys Ltd
General Electric Co Ltd, The
Kandem Electrical Ltd
Livingston Laboratories Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Muirhead & Co Ltd
Nalder Bros & Thompson Ltd
Record Electrical Co Ltd, The
Salford Electrical Instruments Ltd
Solartron Electronic Group Ltd, The
Short Bros & Harland Ltd
Wykeham & Co Ltd, W

Photoelectric controls
★ Circle *No 177* on reply card
Airmec Ltd
Allied Electronics Ltd
Andec Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
British Thomson-Houston Co Ltd, The
Burndept Ltd
Cass & Phillip Ltd
Cawkell Research & Electronics Ltd
Counting Instruments Ltd
Crosfield Ltd, J. F
Craven Electronics Ltd
Danfoss Mfg Co
Dowty Nucleonics Ltd
Elcontrol Ltd
Electronic Machine Co Ltd
Electrical Remote Control Co Ltd
EMI Electronics Ltd
Ericsson Telephones Ltd
Evans Electroselenium Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Hilger & Watts Ltd
Hutcheon Duthie & Son Ltd, R
Integra, Leeds & Northrup Ltd
Joyce, Loebl & Co Ltd
Lancashire Dynamo Electronic Products Ltd
Leland Instruments Ltd
Lock & Co Ltd, A. M
Londex Ltd
Magnetic Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Ltd
Phillips & Bonson Ltd
Racal Engineering Ltd
Radiovisor Parent Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Rheostatic Co Ltd, The
Robinson & Partners Ltd, F. C
Sargrove Electronics Ltd
Sangamo Weston Ltd
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The
Short & Mason Ltd
Siemens Edison Swan Ltd
Solartron Electronic Group Ltd, The
Teledictor Ltd
Universal Control Equipment Ltd

pH controllers and recorders
★ Circle *No 178* on reply card
Analytical Measurements Ltd
Bailey Meters & Controls Ltd
Baird & Tatlock (London) Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Doran Instrument Co Ltd
Electroflo Meters Co Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Farnell Instruments Ltd
Fielden Electronics Ltd
Foxboro-Yoxall Ltd
Griffin & George Ltd
Honeywell Controls Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Ionic Instruments (London) Ltd
Kandem Electrical Ltd
Kent Ltd, George
Lock & Co Ltd, A. M
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Nash & Thompson Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Tintometer Co Ltd
Thermocontrol Installations Co Ltd
Wykeham & Co Ltd, W

Position indicators
★ Circle *No 179* on reply card
Airmec Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Craven Electronics Ltd
Dunford & Elliott (Sheffield) Ltd
Dobbie McInnes Ltd
Dowty Nucleonics Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Ericsson Telephones Ltd
Fielden Electronics Ltd
Firth Cleveland Instruments Ltd
Gordon & Co Ltd, James
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Lock & Co Ltd, A. M
Metropolitan-Vickers Electrical Co Ltd
Measuring Instruments (Pullin) Ltd
Muirhead & Co Ltd
Record Electrical Co Ltd, The
Research & Control Instruments Ltd

Smiths Aircraft Instruments Ltd
Salford Electrical Instruments Ltd
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Telektron (GB) Ltd
Thompson Ltd, J. Langham
Watford Electric & Mfg Co Ltd

Potentiometers
★ Circle *No 180* on reply card
Air Trainers Link Ltd
Allied Electronics Ltd
Ardente Acoustic Laboratories Ltd
Bailey Meters & Controls Ltd
British Electric Resistance Co Ltd, The
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Colvern Ltd
Dubilier Condenser Co (1925) Ltd
Farnell Instruments Ltd
Ferranti Ltd
General Electric Co Ltd, The
Graseby Instruments Ltd
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Morgan Crucible Co Ltd, The
Muirhead & Co Ltd
NSF Ltd
Painton & Co Ltd
Plessey Co Ltd, The
Salford Electrical Instruments Ltd
Thompson Ltd, J Langham
Winston Electronics Ltd

Power factor indicators
★ Circle *No 181* on reply card
Aveley Electric Ltd
Avo Ltd
Cambridge Instrument Co Ltd
Crompton Parkinson Ltd
Electrical Instrument Co (Hillington) Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
Ferranti Ltd
General Electric Co Ltd, The
Kandem Electrical Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Nalder Bros & Thompson Ltd
Record Electrical Co Ltd, The
Robinson & Partners Ltd, F. C
Salford Electrical Instruments Ltd
Solartron Electronic Group Ltd, The

Power units (a.c. and d.c.)
★ Circle *No 182* on reply card
Air Trainers Link Ltd
Airtech Ltd
Andec Ltd
Appleby & Ireland Ltd
All Power Transformers Ltd
Bradley Ltd, G. & E
Correx Communications Equipment (1948) Ltd
Ekco Electronics Ltd
Electric Construction Co Ltd, The
Ericsson Telephones Ltd
English Electric Co Ltd, The
Express Transformers & Controls Ltd
Farnell Instruments Ltd
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
Hirst Electronic Ltd
Harmsworth Townley & Co
JV Radio & Television Ltd
Kasama Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Racal Engineering Ltd
Pye & Co Ltd, W. G
Sanders (Electronics) Ltd, W. H
Savage Ltd, W. Bryan
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd
Thompson Ltd, J. Langham
Tripletone Mfg Co Ltd
Venner Electronics Ltd
Walter Instruments Ltd

Pre-amplifiers
★ Circle *No 183* on reply card
Airtech Ltd
Amos (Electronics) Ltd
Amplivox Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
Andec Ltd
Belling & Lee Ltd
Cawkell Research & Electronics Ltd
Cossor Instruments Ltd
Dulci Co Ltd, The
Dynatron Radio Ltd
Easco Electrical (Holdings) Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd

★ *For further details circle on card facing page A60*

Ericsson Telephones Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
General Radiological Ltd
Glass Developments Ltd
Isotope Developments Ltd
Joyce, Loebl & Co Ltd
JV Radio & Television Ltd
Kelvin & Hughes Ltd
Labgear Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Mullard Ltd
Nagard Ltd
Peto Scott Electrical Instruments Ltd
Plessey Nucleonics Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Siemens Edison Swan Ltd
Sanders (Electronics) Ltd, W. H
Savage, Ltd, W. Bryan
Sunvic Controls Ltd
Telefusion Engineering Ltd (h.f. only)
Walter Instruments Ltd
WS Electronics (Production) Ltd

Pressure indicators, recorders and controllers

★ Circle *No 184* on reply card

Accurate Recording Instrument Co, The
Alexander Controls Ltd
Airflow Developments Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Barnet Instruments Ltd
B & K Laboratories Ltd
Black Automatic Controls Ltd
Bristol's Instrument Co Ltd
British Rototherm Co Ltd, The
Cambridge Instrument Co Ltd
Coley Thermometers Ltd
Combustion Instruments
Danfoss Mfg Co
Drayton Regular & Instrument Co Ltd
Dunford & Elliott (Sheffield) Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foxboro-Yoxall Ltd
General Electric Co Ltd
Gordon & Co Ltd, James
High-Pressure Components Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hymatic Engineering Co Ltd, The
Integra, Leeds & Northrup Ltd
IV Pressure Controllers Ltd
Kelvin & Hughes Ltd
KDG Instruments Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lintronic Ltd
Londex Ltd
Negretti & Zambra Ltd
New Electronic Products Ltd
Norgren Ltd, C. A
Nottingham Thermometer Co Ltd
Payne & Griffiths Ltd
Pressure Control Ltd
Research & Control Instruments Ltd
Rheostatic Co Ltd, The
Samson Controls (London) Ltd
Salford Electrical Instruments Ltd
Sangamo Weston Ltd
Sauter Controls Ltd
Short & Mason Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instruments Division
Southern Instruments Ltd
Sperry Gyroscope Co Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Thompson Ltd, J. Langham
Walker, Crossweller & Co Ltd
Wykeham & Co Ltd, W
Watford Electric & Mnfg Co Ltd

Pressure-gauges

★ Circle *No 185* on reply card

Accurate Recording Instrument Co, The
Appleby & Ireland Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
Barnet Instruments Ltd
Bristol's Instrument Co Ltd
British Rototherm Co Ltd, The
Cambridge Instrument Co Ltd
Coley Thermometers Ltd
Combustion Instruments
Drayton Regulator & Instrument Co Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Foxboro-Yoxall Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hunt & Mitton Ltd

KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Negretti & Zambra Ltd
Nottingham Thermometer Co Ltd
Payne & Griffiths Ltd
Short & Mason Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instrument Division
Southern Instruments Ltd
Taylor Controls Ltd
Zeal Ltd, G. H

Printed circuits

★ Circle *No 186* on reply card

Andec Ltd
Baird Television (Hartley Baird Ltd)
Belling & Lee Ltd (Components)
B & K Laboratories Ltd
Burndept Ltd
Cossor Instruments Ltd
Electronic Components
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Fairey Aviation Co Ltd, The
Ferranti Ltd
General Electric Co Ltd, The
Microcell Electronics
Millett, Levens (Instruments & Engineering) Ltd
NSF Ltd
Plessey Co Ltd, The
Printed Circuit Developments Ltd
Printed Circuits Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Sargrove Electronics
Savage Ltd, W. Bryan
Short Bros & Harland Ltd
Siemens Edison Swan Ltd
Sperry Gyroscope Co Ltd
Technograph Electronic Products Ltd

Probe units

★ Circle *No 187* on reply card

Bailey Meters & Controls Ltd
British Physical Laboratories
Burndept Ltd
Cass & Phillip Ltd
Dynatron Radio Ltd
Ekco Electronics Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Farnell Instruments Ltd
Fleming Radio (Developments) Ltd
Kelvin & Hughes (Industrial) Ltd
Microcell Electronics
Nagard Ltd
Racal Engineering Ltd
Radiovisor Parent Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd

Process timing instruments

★ Circle *No 188* on reply card

Allied Electronics Ltd
Applied Radiation Ltd
Airmec Ltd
Associated Automation Ltd
Baldwin Instrument Co Ltd
Boulton Paul Aircraft Ltd
British Thomson-Houston Co Ltd, The
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
Bruce Peebles & Co Ltd
Burndept Ltd
Cambridge Instrument Co Ltd
Cass & Phillip Ltd
Craven Electronics Ltd
Devon Instruments Ltd
Dunford & Elliott (Sheffield) Ltd
Elcontrol Ltd
Electrical Remote Control Co Ltd
Electronic Instruments Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Emeco Electronics Co
Engel & Gibbs Ltd
Everett, Edgcumbe & Co Ltd
Evans Electronic Developments Ltd
Furzehill Laboratories Ltd
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
Graseby Instruments Ltd
Herbert Ltd, Alfred
Hunt & Mitton Ltd
Igranic Electric Co Ltd
Ilford Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products
Lock & Co Ltd, A. M
Londex Ltd
Magnetic Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Nagard Ltd
Nash & Thompson Ltd
Panax Equipment Ltd
Pye & Co Ltd, W. G
Radiovisor Parent Ltd

Rank Cintel Ltd
Robinson & Partners Ltd, F. C
Sanders (Electronics) Ltd, W. H
Sargrove Electronics Ltd
Sauter Controls Ltd
Solartron Electronic Group Ltd, The
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Teledictor Ltd
Towers & Co Ltd, J. W
Tylors of London Ltd
Universal Control Equipment Ltd
Venner Ltd
Watford Electric & Mfg Co Ltd
Winston Electronics Ltd

Profile indicators

★ Circle *No 189* on reply card

Baldwin Instrument Co Ltd
Beck Ltd, R. & J
Gloster Aircraft Co Ltd
Herbert Ltd, Alfred
Hilger & Watts Ltd
Leech (Rochester) Ltd
Metropolitan-Vickers Electrical Co Ltd
Negretti & Zambra Ltd
Optical Works Ltd
Precision Tool Instrument Co Ltd
Taylor, Taylor & Hobson Ltd
Test Equipment Ltd
Watson, Manesty & Co Ltd
Wickman Ltd

Programme controllers

★ Circle *No 190* on reply card

Associated Automation Ltd
Autophone Ltd
Blickvac Engineering Ltd
Bristol's Instrument Co Ltd
British Tabulating Machine Co Ltd, The
British Thomson-Houston Co Ltd, The
Cambridge Instrument Co Ltd
Cass & Phillip Ltd
Drayton Regulator & Instrument Co Ltd
Dunford & Elliott (Sheffield) Ltd
Elcontrol Ltd
Electrical Remote Control Co Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Ether Ltd
Evershed & Vignoles Ltd
Foster Instrument Co Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
Hunt & Mitton Ltd
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Metropolitan-Vickers Electrical Co Ltd
Negretti & Zambra Ltd
Research & Control Instruments Ltd
Sauter Controls Ltd
Sperry Gyroscope Co Ltd
Taylor Controls Ltd
Telephone Rentals Ltd
Test Equipment Ltd
West Instrument Ltd
WS Electronics (Production) Ltd

Proportional controllers

★ Circle *No 191* on reply card

Bailey Meters & Controls Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Correx Communications Equipment (1948) Ltd
Drayton Regulator & Instrument Co Ltd
Dunford & Elliott (Sheffield) Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Ether Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Negretti & Zambra Ltd
Research & Control Instruments Ltd
Rheostatic Co Ltd, The
Samson Controls (London) Ltd
Sauter Controls Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd
West Instruments Ltd

Pulse height analysers

★ Circle *No 192* on reply card

Aveley Electric Ltd
B & K Laboratories Ltd
British Physical Laboratories
Dynatron Radio Ltd
Ekco Electronics Ltd
EMI Electronics Ltd
Isotope Developments Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M

★ *For further details circle on card facing page A60*

Mullard Equipment Ltd
Racal Engineering Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Sunvic Controls Ltd

Pumps—hydraulic
★ Circle *No 193* on reply card
Airtech Ltd
Automotive Products Co Ltd (Lockheed Hydraulics Division)
Berry & Co Ltd, Henry
Conveyancer Fork Trucks Ltd
Dowty Hydraulic Units Ltd
Exactor Ltd
Fawcett-Finney Ltd
Fraser & Co Ltd, Andrew
Hamworthy Engineering Ltd
Hydraulics & Pneumatics Ltd
Integral Ltd
Keelavite Rotary Pumps & Motors Ltd
Linford Engineering Co Ltd
Metering Pumps Ltd
Oswalds & Ridgway Ltd
Plessey Co Ltd, The
Power Jacks Ltd
Pratt Precision Hydraulics Ltd
Spenborough Engineering Co Ltd
Sperry Gyroscope Co Ltd
Tangyes Ltd
Varley-FMC Ltd
Vickers-Armstrong (Engineers) Ltd

Pyrometers
★ Circle *No 194* on reply card
AEW Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
Baird & Tatlock (London) Ltd
B & K Laboratories Ltd
Bayley, Clanahan & Co Ltd
Cambridge Instrument Co Ltd
Coley Thermometers Ltd
Electrical Instrument Co (Hillington) Ltd, The
Electroflo Meters Co Ltd
Electrothermal Engineering Ltd
Elliott Bros (London) Ltd
Ether Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
Foxboro-Yoxall Ltd
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
Griffin & George Ltd
Headland Engineering Developments Ltd
Honeywell Controls Ltd
Industrial Pyrometer Co Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Land Pyrometers Ltd
Measuring Instruments (Pullin) Ltd
Negretti & Zambra Ltd
Nottingham Thermometer Co Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Smiths Aircraft Instruments Ltd
Tinsley & Co Ltd, H
West Instrument Ltd
Zeal Ltd, G. H

Q-meters
★ Circle *No 195* on reply card
Advance Components Ltd
Aveley Electric Ltd
British Physical Laboratories
Dawe Instruments Ltd
Emeco Electronics Co
Farnell Instruments Ltd
Livingston Laboratories Ltd
Leland Instruments Ltd
Lyons Ltd, Claude
Marconi Instruments Ltd
Robinson & Partners Ltd, F. C
Samwell & Hutton Ltd
Wayne Kerr Laboratories Ltd

Quality control equipment
★ Circle *No 196* on reply card
Baldwin Instrument Co Ltd
B & K Laboratories Ltd
British Insulated Callender's Cables Ltd
Ekco Electronics Ltd
Electro Mechanisms Ltd
Electronic Machine Co Ltd
Elliott Bros (London) Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Honeywell Controls Ltd
JV Radio & Television Ltd
Negretti & Zambra Ltd
Pye & Co Ltd, W. G
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Sanders (Electronics) Ltd, W. H
Tintometer Co Ltd
Wayne Kerr Laboratories Ltd

Ratemeters
★ Circle *No 197* on reply card
Burndept Ltd
Cass & Phillip Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Ericsson Telephones Ltd
Fleming Radio (Developments) Ltd
General Radiological Ltd
Gloster Aircraft Co Ltd
Isotope Developments Ltd
Labgear (Cambridge) Ltd
Lock & Co Ltd, A. M
Nucleonic & Radiological Developments Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Research & Control Instruments Ltd
Teddington Aircraft Controls Ltd

Recorders—miniature
★ Circle *No 198* on reply card
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Barr & Stroud Ltd
Bristol's Instrument Co Ltd
Cambridge Instrument Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Ether Ltd
Everett, Edgcumbe & Co Ltd
Foxboro-Yoxall Ltd
General Electric Co Ltd, The
Honeywell Controls Ltd
Livingston Laboratories Ltd
Rank Cintel Ltd
Record Electrical Co Ltd, The
Research & Control Instruments Ltd
Savage & Parsons Ltd
Sunvic Controls Ltd
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Test Equipment Ltd

Recorders—multipoint
★ Circle *No 199* on reply card
Avimo Ltd
B & K Laboratories
Bailey Meters & Controls Ltd
Cambridge Instrument Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Everett, Edgcumbe & Co Ltd
Foster Instrument Co Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Hendrey Relays Ltd
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
McKellen Automation Ltd
Mervyn Instruments
Negretti & Zambra Ltd
New Electronic Products Ltd
Nash & Thompson Ltd
Nucleonic & Radiological Developments Ltd
Research & Control Instruments Ltd
Savage & Parsons Ltd
Siemens Edison Swan Ltd
Sigma Instrument Co Ltd
Smiths Industrial Instrument Division
Sunvic Controls Ltd
Southern Instruments Computer Division
Winston Electronics Ltd

Recorders—potentiometric
★ Circle *No 200* on reply card
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
McKellen Automation Ltd
Negretti & Zambra Ltd
Pye & Co Ltd, W. G
Research & Control Instruments Ltd
Sangamo Weston Ltd
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd
West Instrument Ltd

Refrigeration controllers
★ Circle *No 201* on reply card
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Danfoss Mfg Co
Honeywell Controls Ltd
Jones & Stevens Ltd
Negretti & Zambra Ltd
Planer Ltd, G. V
Sauter Controls Ltd
Taylor Controls Ltd
Teddington Refrigeration Controls Ltd
Thermocontrol Installations Co Ltd
Watford Electric & Mfg Co Ltd

Relays—a.c
★ Circle *No 202* on reply card
Airedale Electrical & Mfg Co Ltd
Anders Electronics Ltd
Applied Radiation Ltd
Arrow Electric Switches Ltd
Aron Electricity Meter Ltd
ASEA Electric Ltd
Austinlite Ltd
Automatic Telephone & Electric Co Ltd
Autophone Ltd
Besson & Robinson Ltd
British Thomson-Houston Co Ltd, The
Chamberlain & Hookham Ltd
Cuthbert Ltd, Ralph
Danfoss Mfg Co
Davis (Relays) Ltd, Jack
Dependable Relay Co Ltd
"Diamond H" Switches Ltd
Donovan Electrical Co Ltd, The
Electric Construction Co Ltd, The
Electrical Instrument Co (Hillington) Ltd
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
Electro Methods Ltd
EMI Electronics Ltd
Engel & Gibbs Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Ferranti Ltd
Fuller Electrical & Mfg Co Ltd
Geipel Ltd, William
General Electric Co Ltd, The
Honeywell Controls Ltd
Hendrey Relays Ltd
Igranic Electric Co Ltd
Klockner-Moeller England Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Londex Ltd
Lock & Co Ltd, A. M
Magnetic Controls Ltd
Magnetic Devices Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
NSF Ltd
Parkinson & Cowan Instruments
Pell Control Ltd, Oliver
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Pye & Co Ltd, W. G
Record Electrical Co Ltd, The
Reyrolle & Co Ltd, A
Rheostatic Co Ltd, The
Robinson & Partners Ltd, F. C
Salford Electrical Instruments Ltd
Sangamo Weston Ltd
Simmonds Ltd, L. E
Smiths Industrial Instruments Division
Square D Ltd
Standard Telephones & Cables Ltd
Sunvic Controls Ltd
Telephone Mfg Co Ltd
Thermocontrol Installations Co Ltd
Thompson Ltd, J. Langham
Watford Electric & Mfg Co Ltd
West Instrument Ltd

Relays—current
★ Circle *No 203* on reply card
Arrow Electric Switches Ltd
Airedale Electrical & Mfg Co Ltd
Automatic Telephone & Electric Co Ltd
Davis (Relays) Ltd, Jack
"Diamond H" Switches Ltd
Electrical Remote Control Co
Electro-Magnetic Control Co
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Ferranti Ltd
Geipel Ltd, William
General Electric Co Ltd, The
Hendrey Relays Ltd
Igranic Electric Co Ltd
Londex Ltd
Lock & Co Ltd, A. M
Magnetic Controls Ltd
Magnetic Devices Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Record Eectrical Co Ltd, The
Sanders (Electronics) Ltd, W. H
Salford Electrical Instruments Ltd
Simmonds Ltd, L. E
Smiths Industrial Instrument Division
Taylor Electrical Instruments Ltd
Thompson Ltd, J. Langham
Watford Electric & Mfg Co Ltd

Relays—electronic
★ Circle *No 204* on reply card
Allied Electronics Ltd
ADS Relays Ltd

★ *For further details circle on card facing page A60*

Applied Radiation Ltd
ASEA Electric Ltd
Austinlite Ltd
Automatic Telephone & Electric Co Ltd
Aveley Electric Ltd
Bessum & Robinson Ltd
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
Craven Electronics Ltd
Dobbie McInnes Ltd
Danfoss Mfg Co
Dependable Relay Co
"Diamond H" Switches Ltd
Elcontrol Ltd
Electric Construction Co Ltd, The
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
Electro Methods Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Evans Electronic Developments Ltd
Fielden Electronics Ltd
Geipel Ltd, William
General Electric Co Ltd, The
Gordon & Co Ltd, James
Hall (Elec Engineers) Ltd, J Edward
Hendrey Relays Ltd
Honeywell Controls Ltd
Instruments & Controls Ltd
Kent Ltd, George
Lancashire Dynamo Electronic Products Ltd
Laurence, Scott & Electromotors Ltd
Londex Ltd
Lock & Co Ltd, A. M
Magnetic Devices Ltd
Magnetic Controls Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Nalder Bros & Thompson Ltd
New Electronic Products Ltd
Plessey Co Ltd, The
Radiovisor Parent Ltd
Research & Control Instruments Ltd
Reyrolle & Co Ltd, A
Robinson & Partners Ltd, F. C
Sanders (Electronics) Ltd, W. H
Simmonds Ltd, L. E
Standard Telephones & Cables Ltd
Stone Chance Ltd
Solartron Electronic Group Ltd, The
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd
Venner Electronics Ltd
Walter Instruments Ltd
West Instrument Ltd

Relays—frequency
★ Circle *No 205* on reply card
Honeywell Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Record Electrical Co Ltd, The

Relays—heavy duty
★ Circle *No 206* on reply card
Arrow Electric Switches Ltd
Autophone Ltd
Donovan Electrical Co Ltd, The
Electrical Remote Control Co Ltd
General Electric Co Ltd, The
Hendrey Relays Ltd
Igranic Electric Co Ltd
Klöckner-Moeller England Ltd
Londex Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
Metropolitan-Vickers Electrical Co Ltd
Plessey Co Ltd, The
Sanders (Electronics) Ltd, W. H
Simmonds Ltd, L. E
Square D Ltd
Watford Electric & Mfg Co Ltd

Relays—instrument control
★ Circle *No 207* on reply card
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Electrical Remote Control Co Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
General Electric Co Ltd, The
Gordon & Co Ltd, James
Hendrey Relays Ltd
Honeywell Controls Ltd
KDG Instruments Ltd
Kingston Control Systems Ltd
Londex Ltd
Magnetic Controls Ltd
Plessey Co Ltd, The
Rheostatic Co Ltd, The
Simmonds Ltd, L. E
Smiths Industrial Instrument Division
Sunvic Controls Ltd
Taylor Electrical Instruments Ltd
Teddington Industrial Equipment Ltd

Relays—latch
★ Circle *No 208* on reply card
Arrow Electric Switches Ltd
Donovan Electrical Co Ltd, The
Davis (Relays) Ltd, Jack
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
English Electric Co Ltd, The
Igranic Electric Co Ltd
Londex Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
Sauter Controls Ltd
Simmonds Ltd, L. E
Square D Ltd
Standard Telephones & Cables Ltd
Telephone Mfg Co Ltd
Watford Electric & Mfg Co Ltd

Relays—magnetic
★ Circle *No 209* on reply card
ADS Relays Ltd
Arrow Electric Switches Ltd
Automatic Telephone & Electric Co Ltd
Autophone Ltd
Danfoss Mfg Co
Davis (Relays) Ltd, Jack
"Diamond H" Switches Ltd
Donovan Electrical Co Ltd, The
Electro-Magnetic Control Co
Electrical Remote Control Co Ltd
English Electric Co Ltd, The
EMI Electronics Ltd
Ferranti Ltd
General Electric Co Ltd, The
Hendrey Relays Ltd
Honeywell Controls Ltd
Igranic Electric Co Ltd
Londex Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Plessey Co Ltd, The
Rheostatic Co Ltd, The
Sanders (Electronics) Ltd, W. H
Sauter Controls Ltd
Simmonds Ltd, L. E
Smiths Aircraft Instruments Ltd
Sperry Gyroscope Co Ltd
Square D Ltd
Watford Electric & Mfg Co Ltd

Relays—mercury
★ Circle *No 210* on reply card
Davis (Relays) Ltd, Jack
Dubilier Condenser Co (1925) Ltd
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
General Electric Co Ltd, The
Hendrey Relays Ltd
Londex Ltd
Magnetic Controls Ltd
Simmonds Ltd, L. E
Watford Electric & Mfg Co Ltd

Relays—miniature
★ Circle *No 211* on reply card
Automatic Telephone & Electric Co Ltd
Arrow Electric Switches Ltd
Besson & Robinson Ltd
Davis (Relays) Ltd, Jack
"Diamond H" Switches Ltd
EMI Electronics Ltd
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
General Electric Co Ltd, The
Londex Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
New Electronic Products Ltd
NSF Ltd
Pell Control Ltd, Oliver
Plessey Co Ltd, The
Sangamo Weston Ltd
Siemens Edison Swan Ltd
Simmonds Ltd, L. E
Sperry Gyroscope Co Ltd
Standard Telephones & Cables Ltd
Walter Instruments Ltd

Relays—overload
★ Circle *No 212* on reply card
Arrow Electric Switches Ltd
Danfoss Mfg Co
Davis (Relays) Ltd, Jack
Donovan Electrical Co Ltd, The
Electrical-Remote Control Co Ltd
Electro-Magnetic Control Co
English Electric Co Ltd, The
Hendrey Relays Ltd
Igranic Electric Co Ltd
Klöckner-Moeller England Ltd
Laurence, Scott & Electromotors Ltd
Lock & Co Ltd, A. M
Londex Ltd
Metropolitan-Vickers Electrical Co Ltd, The
Magnetic Controls Ltd
Magnetic Devices Ltd
P & B Engineering Co Ltd, The
Record Electrical Co Ltd, The
Salford Electrical Instruments Ltd
Square D Ltd
Watford Electric & Mfg Co Ltd

Relays—pneumatic
★ Circle *No 213* on reply card
Associated Automation Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
British Arca Regulators Ltd
Drayton Regulator & Instrument Co Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
Gordon & Co Ltd, James
Igranic Electric Co Ltd
Kent Ltd, George
Mead & Phasey Ltd
Mechanical & Electronic Porducts Ltd
Negretti & Zambra Ltd
Sauter Controls Ltd
Square D Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Teddington Aircraft Controls Ltd

Relays—polarized
★ Circle *No 214* on reply card
Davis (Relays) Ltd, Jack
EMI Electronics Ltd
Ericsson Telephones Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Londex Ltd
Magnetic Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Sanders (Electronics) Ltd, W. H
Simmonds Ltd, L. E
Standard Telephones & Cables Ltd
Telephone Mfg Co Ltd

Relays—power
★ Circle *No 215* on reply card
Davis (Relays) Ltd, Jack
Donovan Electrical Co Ltd, The
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
English Electric Co Ltd, The
Gordon & Co Ltd, James
Hendrey Relays Ltd
Hirst Electronic Ltd
Igranic Electric Co Ltd
Londex Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
Metropolitan-Vickers Electrical Co Ltd
Plessey Co Ltd, The
Watford Electric & Mfg Co Ltd

Relays—sensitive
★ Circle *No 216* on reply card
Appleby & Ireland Ltd
Autophone Ltd
Davis (Relays) Ltd, Jack
Electrical Remote Control Co Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Gordon & Co Ltd, James
Hendrey Relays Ltd
Londex Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
Metropolitan-Vickers Electrical Co Ltd
Plessey Co Ltd, The
Record Electrical Co Ltd, The
Savage & Parsons Ltd
Simmonds Ltd, L. E
Smiths Industrial Instrument Division
Telephone Mfg Co Ltd
Thompson Ltd, J. Langham
Watford Electric & Mfg Co Ltd

Relays—stepping
★ Circle *No 217* on reply card
Autophone Ltd
Electrical Remote Control Co Ltd
Electro-Magnetic Control Co
Lock & Co Ltd, A. M
Londex Ltd
NSF Ltd
Standard Telephones & Cables Ltd

Relays—telephone
★ Circle *No 218* on reply card
ADS Relays Ltd
Automatic Telephone & Electric Co Ltd
Autophone Ltd
Davis (Relays) Ltd, Jack
Electrical Remote Control Co Ltd
Ericsson Telephones Ltd
Livingston Laboratories Ltd
Magnetic Controls Ltd
Magnetic Devices Ltd
Plessey Co Ltd, The
Sanders (Electronics) Ltd, W. H
Siemens Edison Swan Ltd
Simmonds Ltd, L. E
Standard Telephones & Cables Ltd
Telephone Mfg Co Ltd

Relays—temperature
★ Circle *No 219* on reply card
British Arca Regulators Ltd
Danfoss Mfg Co
Foster Instrument Co Ltd
Gordon & Co Ltd, James
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd

★ *For further details circle on card facing page A60*

Metropolitan-Vickers Electrical Co Ltd
Salford Electrical Instruments Ltd
Sunvic Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd
Townson & Mercer Ltd
Watford Electric & Mfg Co Ltd

Relays—time delay
★ Circle *No 220* on reply card
Allied Electronics Ltd
ASEA Electric Ltd
Austinlite Ltd
B & K Laboratories Ltd
Boulton Paul Aircraft Ltd
British Thomson-Houston Co Ltd, The
Chamberlain & Hookham Ltd
Cuthbert Ltd, Ralph
Davis (Relays) Ltd, Jack
Donovan Electrical Co Ltd, The
Elcontrol Ltd
Electrical Remote Control Co Ltd
Electro Methods Ltd
Electrothermal Engineering Ltd
Electro-Magnetic Control Co Ltd
English Electric Co Ltd, The
Geipel Ltd, William
General Electric Co Ltd, The
Gordon & Co Ltd, James
Hall (Elec Engineers) Ltd, J. Edward
Hendrey Relays Ltd
Hirst Electronic Ltd
Igranic Electric Co Ltd
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Londex Ltd
Magnetic Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Nagard Ltd
Plessey Co Ltd, The
Research & Control Instruments Ltd
Reyrolle & Co Ltd, A
Simmonds Ltd, L. E
Standard Telephones & Cables Ltd
Square D Ltd
Sunvic Controls Ltd
Thermocontrol Installations Co Ltd
Watford Electric & Mfg Co Ltd

Relays—transformer
★ Circle *No 221* on reply card
Electro-Magnetic Control Co
EMI Electronics Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd

Relays—uniselector
★ Circle *No 222* on reply card
Automatic Telephone & Electric Co Ltd
Autophone Ltd
Davis (Relays) Ltd, Jack
English Electric Co Ltd, The
Ericsson Telephones Ltd
General Electric Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd

Remote control & supervisory apparatus & systems
★ Circle *No 223* on reply card
Appleby & Ireland Ltd
Associated Automation Ltd
Automatic Telephone & Electric Co Ltd
Bailey Meters & Controls Ltd
Bell Precision Engineering Co Ltd
Bloctube Controls Ltd
British Thomson-Houston Co Ltd, The
Bruce Peebles & Co Ltd
Burndept Ltd
Chatwood-Milner Ltd
Cass & Phillips Ltd
Correx Communications Equipment (1948) Ltd
Dunford & Elliott (Sheffield) Ltd
Electrical Remote Control Co Ltd
Electro-Hydraulics Ltd
Elcontrol Ltd
Electroflo Meters Co Ltd
Electronic Machine Co Ltd
Electric Construction Co Ltd, The
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Evershed & Vignoles Ltd
Exactor Ltd
Fielden Electronics Ltd
Fischer & Porter Ltd
General Electric Co Ltd, The
Globe Pneumatic Engineering Co Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Hall & Co Ltd, Matthew
Hendrey Relays Ltd
Hobson Ltd, H. M
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
Kent Ltd, George
Ketay Ltd
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lincoln Electric Co Ltd
Lock & Co Ltd, A. M
Londex Ltd
Magnetic Controls Ltd
Measurement Ltd
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Muirhead & Co Ltd
Nalder Bros & Thompson Ltd
Negretti & Zambra Ltd
NSF Ltd
Nuclear Engineering Ltd
Palatine Tool & Engineering Co (Surbiton) Ltd
Parkinson & Cowan Instruments
Perl Controls Ltd
Pell Control Ltd, Oliver
Plessey Nucleonics Ltd
Pye & Co Ltd, W. G
Racal Engineering Ltd
Radiovisor Parent Ltd
Research & Control Instruments Ltd
Reyrolle & Co Ltd, A
Robinson & Partners Ltd, F. C
Rotameter Mfg Co Ltd
Salford Electrical Instruments Ltd
Sanders (Electronics) Ltd, W. H.
Samson Controls (London) Ltd
Sauter Controls Ltd
Savage & Parsons Ltd
Siemens Edison Swan Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The
Sperry Gyroscope Co Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Teleflex Products Ltd
Telektron (GB) Ltd
Test Equipment Ltd
Thermocontrol Installations Co Ltd
Tylors of London Ltd
Western Mfg (Reading) Ltd
Watford Electric & Mfg Co Ltd
West Instrument Ltd
Wilson & Partners Ltd, A. C
WS Electronics (Production) Ltd

Roughness indicators
★ Circle *No 224* on reply card
B & K Laboratories Ltd
British Physical Laboratories
Emeco Electronics Co
Gallenkamp & Co Ltd, A
Herbert Ltd, Alfred
Hilger & Watts Ltd
Research & Control Instruments Ltd
Sigma Instrument Co Ltd
Solus-Schall Ltd
Taylor, Taylor & Hobson Ltd
Telephone Rentals Ltd

Salinometers
★ Circle *No 225* on reply card
Cambridge Instrument Co Ltd
Camlab (Glass) Ltd
Cossor Instruments Ltd
Dobbie McInnes Ltd
Evershed & Vignoles Ltd
Griffin & George Ltd
Hearson & Co Ltd, Charles
Ionic Instruments (London) Ltd
Kelvin & Hughes Ltd
Poulten, Selfe & Lee Ltd
Short & Mason Ltd
Stanley & Co Ltd, W. F
Taylor Controls Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Zeal Ltd, G. H

Servo system analysers
★ Circle *No 226* on reply card
Airmec Ltd
Associated Automation Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Dawe Instruments Ltd
Dynatron Radio Ltd
EMI Electronics Ltd
General Electric Co Ltd, The
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Nagard Ltd
Pullin & Co Ltd, R. B
Research & Control Instruments Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The

Ship stabilising control gear systems
★ Circle *No 227* on reply card
Gloster Aircraft Co Ltd
Muirhead & Co Ltd
Saunders-Roe Ltd
Sperry Gyroscope Co Ltd

Signal generators
★ Circle *No 228* on reply card
Advance Components Ltd
Aeronautical & General Instruments Ltd
Airmec Ltd
Avo Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Bradley Ltd, G. & E
British Physical Laboratories
Cass & Phillip Ltd
Dowty Nucleonics Ltd
Emeco Electronics Ltd
English Electric Co Ltd, The
Farnell Instruments Ltd
Furzehill Laboratories Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Hill Ltd
Holiday & Hemmerdinger Ltd
JV Radio & Television Ltd
Kasama Electronics Ltd
Lancashire Dynamo & Crypto Ltd
Laurence, Scott & Electromotors Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Lyons Ltd, Claude
Marconi Instruments Ltd
Metrix Instruments Ltd
Muirhead & Co Ltd
Pye & Co Ltd, W. G
Rank Cintel Ltd
Research & Control Instruments Ltd
Smurthwaite Electronics
Sanders (Electronics) Ltd, W. H
Servomex Controls Ltd
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd
Taylor Electrical Instruments Ltd
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Smoke density indicators and recorders
★ Circle *No 229* on reply card
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Electro-Magnetic Control Co
Electronic Machine Co Ltd
Electronic Switchgear (London) Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Ether Ltd
Evans Electroselenium Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
General Electric Co Ltd, The
Honeywell Control Ltd
Integra, Leeds & Northrup Ltd
Instruments & Controls Ltd
Kelvin & Hughes Ltd
Kingston Control Systems Ltd
Lock & Co Ltd, A. M
Lancashire Dynamo Eectronic Products Ltd
Londex Ltd
Mine Safety Appliances Ltd
Nash & Thompson Ltd
Radiovisor Parent Ltd
Sargrove Electronics Ltd
Shandon Scientific Co Ltd
Trist & Co Ltd, Ronald

Solenoids
★ Circle *No 230* on reply card
Airtech Ltd
Andec Ltd
Anders Electronics Ltd
Black Automatic Controls Ltd
Cass & Phillip Ltd
Conveyancer Fork Trucks Ltd
Dunford & Elliott (Sheffield) Ltd
Electro Methods Ltd
Electro-Magnetic Control Co
Electro Hydraulics Ltd
Graseby Instruments Ltd
Jones, Tate & Co Ltd
Hendrey Relays Ltd
Hilton Electric Co Ltd
Igranic Electric Co Ltd
Magnetic Devices Ltd
Magnetic Valve Co Ltd
Metropolitan-Vickers Electrical Co Ltd, The
NSF Ltd
Pell Control Ltd, Oliver
Plessey Co Ltd, The
Phillips Control (GB) Ltd
Robinson & Partners Ltd, F. C
Sterling Instrument Co Ltd
Taylor Controls Ltd
Teledictor Ltd
Telemeters Ltd
Thermocontrol Installations Co Ltd
Watford Electric & Mfg Co Ltd
Westool Ltd
Woden Transformer Co Ltd

Sorting equipment
★ Circle *No 231* on reply card
Cambridge Instrument Co Ltd
Isotope Developments Ltd

★ *For further details circle on card facing page A60*

Lock & Co Ltd, A. M
Lancashire Dynamo Electronic Products Ltd
Rank Cintel Ltd
Sigma Instrument Co Ltd
Solartron Electronic Group Ltd
Teledictor Ltd

Sound level indicators
★ Circle *No 232* on reply card
Aveley Electric Ltd
B & K Laboratories Ltd
Cawkell Research & Electronics Ltd
Dawe Instruments Ltd
Farnell Instruments Ltd
Livingston Laboratories Ltd
Lyons Ltd, Claude
Robinson & Partners Ltd, F. C
Solartron Electronic Group Ltd, The
Taylor Electrical Instruments Ltd

Specific gravity indicators, controllers and recorders
★ Circle *No 233* on reply card
Bailey Meters & Controls Ltd
Bristol's Instrument Co Ltd
Crosby Valve & Engineering Co Ltd
Ekco Electronics Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fisher Governor Co Ltd
Fischer & Porter Ltd
Foxboro-Yoxall Ltd
Honeywell Controls Ltd
Instruments & Controls Ltd
Kent Ltd, George
Lock & Co Ltd, A. M
Negretti & Zambra Ltd
Pye & Co Ltd, W. G
Reavell & Co
Rotameter Co Ltd
Short & Mason Ltd
Sunvic Controls Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Townson & Mercer Ltd

Spectrum analysers
★ Circle *No 234* on reply card
B & K Laboratories Ltd
Emeco Electronics Ltd
Furzehill Laboratories Ltd
Griffin & George Ltd
Hilger & Watts Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Racal Engineering Ltd
Winston Electronics Ltd

Speed indicators, controllers and recorders
★ Circle *No 235* on reply card
B & K Laboratories Ltd
British Physical Laboratories
British Thomson-Houston Co Ltd, The
Bruce, Peebles & Co Ltd
Carter & Co Ltd, B. & F
Crompton Parkinson Ltd
Craven Electronics Ltd
Dawe Instruments Ltd
Dobbie McInnes Ltd
Elliott Bros (London) Ltd
Engelhard Industries Ltd
English Electric Co Ltd, The
Ericsson Telephones Ltd
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Gordon & Co Ltd, James
Herbert Ltd, Alfred
Honeywell Controls Ltd
Igranic Electric Co Ltd
Isenthal & Co Ltd
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
Labgear Ltd
Laurence, Scott & Electromotors Ltd
Lancashire Dynamo Electronic Products Ltd
Lyons Ltd, Claude
Measuring Instruments (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Plessey Co Ltd, The
Racal Engineering Ltd
Record Electrical Co Ltd, The
Sanders (Electronics) Ltd, W. H
Servomex Controls Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instruments Division
Short & Mason Ltd
Sperry Gyroscope Co Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Thompson Ltd, J. Langham
Tinsley & Co Ltd, H
Venner Electronics Ltd
Vernons Industries Ltd

Stabilisers
★ Circle *No 236* on reply card
Advance Components Ltd
Airmec Ltd
All-Power Transformers Ltd
Allied Electronics Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
British Electric Resistance Co Ltd
British Power Transformers Co Ltd
Cawkell Research & Electronics Ltd
Doran Instrument Co Ltd
English Electric Valve Co Ltd
Ericsson Telephones Ltd
Ferranti Ltd
General Electric Co Ltd, The
General Radiological Ltd
Goodmans Industries Ltd
Gresham Transformers Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Microcell Electronics
Mullard Ltd
Plessey Co Ltd, The
Radiovisor Parent Ltd
Research & Control Instruments Ltd
Servomex Controls Ltd
Siemens Edison Swan Ltd
Tinsley & Co Ltd, H

Strain gauges
★ Circle *No 237* on reply card
Cussons Ltd, G
Elliott Bros (London) Ltd
Farnell Instruments Ltd
Hilger & Watts Ltd
Kelvin & Hughes Ltd
Leland Instruments Ltd
Research & Control Instruments Ltd
Salford Electrical Instruments Ltd
Saunders-Roe Ltd
Technical Ceramics Ltd
Teddington Industrial Equipment Ltd
Tinsley & Co Ltd, H

Stress-strain analysers
★ Circle *No 238* on reply card
B & K Laboratories Ltd
Counting Instruments Ltd
Croydon Precision Instruments Co
Electro-Mechanisms Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Microcell Electronics
Mullard Ltd
New Electronic Products Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Savage & Parsons Ltd
Southern Instruments Ltd
Technical Ceramics Ltd
Technograph Electronic Products Ltd
Wykeham & Co Ltd, W

Stress-strain indicators and recorders
★ Circle *No 239* on reply card
Airtech Ltd
B & K Laboratories Ltd
Counting Instruments Ltd
Croydon Precision Instruments Co
Electro-Mechanisms Ltd
Fielden Electronics Ltd
General Electric Co Ltd, The
Integra, Leeds & Northrup Ltd
Kelvin & Hughes Ltd
Microcell Electronics
Mullard Ltd
New Electronic Products Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Savage & Parsons Ltd
Southern Instruments Ltd
Technical Ceramics Ltd
Technograph Electronic Products Ltd
Wykeham & Co Ltd, W

Stroboscopes
★ Circle *No 240* on reply card
Allied Electronics Ltd
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
Craven Electronics Ltd
Dawe Instruments Ltd
Dobbie McInnes Ltd
EMI Electronics Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
Graseby Instruments Ltd
Griffin & George Ltd
Herbert Ltd, Alfred
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Lock & Co Ltd, A. M
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Savage & Parsons Ltd
Shandon Scientific Co Ltd
Tinsley & Co Ltd, H
Turner Electrical Instruments Ltd, Ernest

Switches—pressure
★ Circle *No 241* on reply card
Cass & Phillip Ltd
Dowty Nucleonics Ltd
KDG Instruments Ltd
Lock & Co Ltd, A. M
Londex Ltd
MB Metals Ltd
Nash & Thompson Ltd
Nottingham Thermometer Co Ltd
Painton & Co Ltd
Square D Ltd
Thermal Control Co Ltd
Teddington Aircraft Controls Ltd

Synchros
★ Circle *No 242* on reply card
British Thomson-Houston Co Ltd, The
Brown Ltd, S. G
Elliott Bros (London) Ltd
English Electric Co Ltd, The
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
General Electric Co Ltd, The
Kelvin & Hughes Ltd
Ketay Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Smiths Aircraft Instruments Ltd
Sperry Gyroscope Co Ltd

Synchro test equipment
★ Circle *No 243* on reply card
Brown Ltd, S. G
English Electric Co Ltd, The
General Electric Co Ltd, The
Muirhead & Co Ltd
Pullin & Co Ltd, R. B
Solartron Electronic Group Ltd, The
Sperry Gyroscope Co Ltd

Tachogenerators
★ Circle *No 244* on reply card
Aveley Electric Ltd
British Thomson-Houston Co Ltd, The
Brown Ltd, S. G.
Crompton Parkinson Ltd
Electro Methods Ltd
Elliott Bros (London) Ltd
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Ketay Ltd
Laurence, Scott & Electromotors Ltd
Metropolitan-Vickers Electrical Co Ltd
Muirhead & Co Ltd
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Racal Engineering Ltd
Record Electrical Co Ltd, The
Sangamo Weston Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instruments Ltd
Sperry Gyroscope Co Ltd
Vactric (Control Equipment) Ltd
Western Mfg (Reading) Ltd

Tachometers—centrifugal
★ Circle *No 245* on reply card
Andec Ltd
British Physical Laboratories
CNS Instruments Ltd
Dawe Instruments
EMI Electronics Ltd
Everett, Edgcumbe & Co Ltd
Findlay & Co
General Electric Co Ltd, The
Kelvin & Hughes Ltd
New Electronic Products Ltd
Parkinson & Cowan Instruments
Pullin & Co Ltd, R. B
Sangamo Weston Ltd
Sperry Gyroscope Co Ltd

Tachometers—electric & electromagnetic
★ Circle *No 246* on reply card
B & K Laboratories Ltd
British Physical Laboratories
British Thomson-Houston Co Ltd, The
Crompton Parkinson Ltd
Dowty Nucleonics Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
English Electric Co Ltd, The
Evershed & Vignoles Ltd
Farnell Instruments Ltd
Lancashire Dynamo Electronic Products Ltd
Mercer Ltd, Thomas
Pullin & Co Ltd, R. B
Racal Engineering Ltd
Record Electrical Co Ltd, The
Smiths Aircraft Instruments Ltd
Smiths Industrial Instrument Division
Thompson Ltd, J. Langham

Tape punching units
★ Circle *No 247* on reply card
Associated Automation Ltd
British Tabulating Machine Co Ltd, The
Creed & Co Ltd
Ericsson Telephones Ltd
Ferranti Ltd
IBM (United Kingdom) Ltd

Teaching machines
★ Circle *No 248* on reply card
Air Trainers Link Ltd
Redifon Ltd
Sanders (Electronics) Ltd, W. H
Saunders-Roe Ltd
Solartron Electronic Group Ltd, The

★ *For further details circle on card facing page A60*

Telemetering systems
★ Circle *No 249* on reply card
Airtech Ltd
Appleby & Ireland Ltd
Armstrong-Whitworth Aircraft Ltd, Sir W. G
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Bristol's Instrument Co Ltd
British Thomson-Houston Co Ltd, The
Burndept Ltd
Bruce Peebles & Co Ltd
Cheltenham Auto Controls Ltd
Dunford & Elliott (Sheffield) Ltd
Electroflo Meters Co Ltd
Electro Mechanisms Ltd
Electronic Instruments Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Ericsson Telephones Ltd
Ether Ltd
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foxboro-Yoxall Ltd
General Electric Co Ltd, The
Integra, Leeds & Northrup Ltd
Kent Ltd, George
Measurement Ltd
Measuring Equipment (Pullin) Ltd
Metropolitan-Vickers Electrical Co Ltd
Microcell Electronics
Parkinson & Cowan Instruments
Plessey Co Ltd, The
Pullin & Co Ltd, R. B
Rank Cintel Ltd
Sperry Gyroscope Co Ltd
Standard Telephones & Cables Ltd
Sunvic Controls Ltd
Thompson Ltd, J. Langham
Vactric (Control Equipment) Ltd
Wykeham & Co Ltd, W
WS Electronics (Production) Ltd

Telephone & telecommunications equipment
★ Circle *No 250* on reply card
Amplivox Ltd
Automatic Telephone & Electric Co Ltd
Autophone Ltd
British Sarozal Ltd
Brown Ltd, S. G
Bloctube Controls Ltd
Burndept Ltd
Creed & Co Ltd
Davis (Relays) Ltd, Jack
Easco Electrical (Holdings) Ltd
Ekco Electronics Ltd
Ericsson Telephones Ltd
General Electric Co Ltd, The
JV Radio & Television Ltd
Mullard Equipment Ltd
Paul Ltd, K. S
Plessey Co Ltd, The
Racal Engineering Ltd
Solartron Electronic Group Ltd, The
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd
Telefusion Engineering Ltd
Telephone Mfg Co Ltd
Telephone Rentals Ltd
Wayne Kerr Laboratories Ltd
Winston Electronics Ltd
Wykeham & Co Ltd, W

Television—industrial
★ Circle *No 251* on reply card
Baird Television (Hartley-Baird Ltd)
B & K Laboratories Ltd
EMI Electronics Ltd
Livingston Laboratories Ltd
Marconi Wireless Telegraph Co Ltd, The
Pye Ltd (Industrial TV division)
Rank Cintel Ltd
Research & Control Instruments Ltd
Siemens Edison Swan Ltd

Temperature—alarm systems
★ Circle *No 252* on reply card
Airtech Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
British Rototherm Co Ltd, The
Dunford & Elliott (Sheffield) Ltd
Elliott Bros (London) Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
Gordon & Co Ltd, James
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
MB Metals Ltd
Negretti & Zambra Ltd
Short & Mason Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd

Temperature indicators, controllers and recorders
★ Circle *No 253* on reply card
Accurate Recording Instrument Co, The
Airmec Ltd
Andec Ltd
Appleby & Ireland Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
Bristol's Instrument Co Ltd
British Rototherm Co Ltd, The
British Thomson-Houston Co Ltd, The
Cambridge Instrument Co Ltd
Coley Thermometers Ltd
Dunford & Elliott (Sheffield) Ltd
Drayton Regulator & Instrument Co Ltd
Electro Methods Ltd
English Electric Co Ltd, The
Elliott Bros (London) Ltd
Ether Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Foster Instrument Co Ltd
General Electric Co Ltd, The
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Headland Engineering Developments Ltd
Honeywell Controls Ltd
Hunt & Mitton Ltd
Industrial Pyrometer Co Ltd
Isenthal & Co Ltd
Integra, Leeds & Northrup Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Lancashire Dynamo Electronic Products Ltd
Lock & Co Ltd, A. M
Negretti & Zambra Ltd
Perl Controls Ltd
Plessey Co Ltd, The
Pye & Co Ltd, W. G
Radiovisor Parent Ltd
Rheostatic Co Ltd, The
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Samson Controls (London) Ltd
Sangamo Weston Ltd
Sauter Controls Ltd
Short & Mason Ltd
Savage & Parsons Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instrument Division
Stanley & Co Ltd, W. F
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd
West Instrument Ltd
Watford Electric & Mfg Co Ltd
Wykeham & Co Ltd, W
Zeal Ltd, G. H

Tension indicators and controllers
★ Circle *No 254* on reply card
Appleby & Ireland Ltd
Cambridge Instrument Co Ltd
Davy & United Engineering Co Ltd
English Electric Co Ltd, The
Igranic Electric Co Ltd
Lancashire Dynamo Electronic Products Ltd
Metropolitan-Vickers Electrical Co Ltd
Short & Mason Ltd
Smiths Industrial Instrument Division
Taylor Controls Ltd
Thompson Ltd, J. Langham

Textile testing apparatus
★ Circle *No 255* on reply card
Ashworth & Co Ltd, Thomas
B & K Laboratories Ltd
Bruce Peebles & Co Ltd
Bradley Ltd, G. & E
Cambridge Instrument Co Ltd
Evans Electroselenium Ltd
Farnell Instruments Ltd
Fielden Electronics Ltd
Griffin & George Ltd
Instruments & Controls Ltd
Jones & Stevens Ltd
Pye & Co Ltd, W. G
Short & Mason Ltd
Wykeham & Co Ltd, W

Thermistors
★ Circle *No 256* on reply card
Holiday & Hemmerdinger Ltd
Le Carbone (Great Britain) Ltd
Mullard Ltd
Plessey Co Ltd, The
Standard Telephones & Cables Ltd
Thermocontrol Installations Co Ltd
Welwyn Electrical Laboratories Ltd

Thermocouples—base metal
★ Circle *No 257* on reply card
Bailey Meters & Controls Ltd
British Driver-Harris Co Ltd
Cambridge Instrument Co Ltd
Coley Thermometers Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Ether Ltd
Foster Instrument Co Ltd
Griffin & George Ltd
Honeywell Controls Ltd
Industrial Pyrometer Co Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Land Pyrometers Ltd
Lock & Co Ltd, A. M
MB Metals Ltd
Nottingham Thermometer Co Ltd
Pyrotenax Ltd
Research & Control Instruments Ltd
Smiths Aircraft Instruments Ltd
Sifam Electrical Instruments Ltd
Turner Electrical Instruments Ltd, Ernest

Thermocouples—contact type
★ Circle *No 258* on reply card
Accurate Recording Instrument Co, The
Bailey Meters & Controls Ltd
British Rototherm Co Ltd, The
Cambridge Instrument Co Ltd
Eectroflo Meters Co Ltd
Engel & Gibbs Ltd
Gallenkamp & Co Ltd, A
Graviner Mfg Co Ltd
Griffin & George Ltd
Hearson & Co Ltd, Charles
Honeywell Controls Ltd
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
KDG Instruments Ltd
MB Metals Ltd
Negretti & Zambra Ltd
Perl Controls Ltd
Robinson & Partners Ltd, F. C
Shandon Scientific Co Ltd
Short & Mason Ltd
Taylor Controls Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Zeal Ltd, G. H

Thermocouples—rare metal
★ Circle *No 259* on reply card
Bailey Meters & Controls Ltd
Engelhard Industries Ltd (Baker Platinum Division)
Cambridge Instrument Co Ltd
Elliott Bros (London) Ltd
Ether Ltd
Electroflo Meters Co Ltd
Foster Instrument Co Ltd
Griffin & George Ltd
Hilger & Watts Ltd
Honeywell Controls Ltd
Industrial Pyrometer Co Ltd, The
Instruments & Controls Ltd
Integra, Leeds & Northrup Ltd
Kandem Electrical Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Research & Control Instruments Ltd
Smiths Aircraft Instruments Ltd
Turner Electrical Instruments Ltd, Ernest

Thermometers
★ Circle *No 260* on reply card
Accurate Recording Instrument Co
Bailey Meters & Controls Ltd
Barnet Instruments Ltd
Bayley, Clanahan & Co Ltd
British Rototherm Co Ltd, The
Cambridge Instrument Co Ltd
Camlab (Glass) Ltd
Coley Thermometers Ltd
Electro Mechanisms Ltd
Elliott Bros (London) Ltd
Elliott Ltd, H. J
Fielden Electronics Ltd
Foster Instrument Co Ltd
Gallenkamp & Co Ltd, A
Griffin & George Ltd
Headland Engineering Developments Ltd
Integra, Leeds & Northrup Ltd
KDG Instruments Ltd
Kelvin & Hughes Ltd
Kingston Control Systems Ltd
Lock & Co Ltd, A. M
Negretti & Zambra Ltd
Nottingham Thermometer Co Ltd
Pye & Co Ltd, W. G
Rheostatic Co Ltd, The
Savage & Parsons Ltd
Short & Mason Ltd
Smiths Aircraft Instruments Ltd
Smiths Industrial Instruments Division
Stanley & Co Ltd, W. F
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Towers & Co Ltd, J. W
Zeal Ltd, G. H

★ *For further details circle on card facing page A50*

Thermopiles
★ Circle *No 261* on reply card
Cambridge Instrument Co Ltd
Ether Ltd
Griffin & George Ltd
Hilger & Watts Ltd
Integra, Leeds & Northrup Ltd
West Instrument Ltd

Thermostats
★ Circle *No 262* on reply card
Accurate Recording Instrument Co, The
Associated Automation Ltd
B & K Laboratories Ltd
Belling & Lee Ltd
Black Automatic Controls Ltd
British Arca Regulators Ltd
British Rototherm Co Ltd, The
British Thermostat Co Ltd, The
Camlab (Glass) Ltd
CNS Instruments Ltd
Cambridge Instrument Co Ltd
Danfoss Mfg Co
Darton & Co Ltd, F
"Diamond H" Switches Ltd
De La Rue Ltd, Thomas (Potterton Division)
Drayton Regulator & Instrument Co Ltd
Electro Methods Ltd
Electrothermal Engineering Ltd
Evans Electronic Developments Ltd
Fielden Electronics Ltd
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Graviner Mfg Co Ltd
Griffin & George Ltd
Hearson & Co Ltd, Charles
Honeywell Controls Ltd
Integra, Leeds & Northrup Ltd
Instruments & Controls Ltd
Kandem Electrical Ltd
Kingston Control Systems Ltd
Laboratory Equipment (London) Ltd
Negretti & Zambra Ltd
Otter Controls Ltd
Perl Controls Ltd
Process Control Gear Ltd
Research & Control Instruments Ltd
Rheostatic Co Ltd, The
Samson Controls (London) Ltd
Salford Electrical Instruments Ltd
Sauter Controls Ltd
Short & Mason Ltd
Siemens Edison Swan Ltd
Smiths Industrial Instruments Division
Stonebridge Electrical Co Ltd, The
Spirax-Sarco Ltd
Sunvic Controls Ltd
Teddington Aircraft Controls Ltd
Teddington Industrial Equipment Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Thermostatic Control Co, The
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Western Mfg Co Ltd
Weyers Bros Ltd

Thickness gauges—eddy current
★ Circle *No 263* on reply card
Baldwin Instrument Co Ltd
B & K Laboratories Ltd
British Physical Laboratories
Burndept Ltd
Dawe Instruments Ltd
Ekco Electronics Ltd
Evershed & Vignoles Ltd
Farnell Instruments Ltd
General Electric Co Ltd, The
General Radiological Ltd
Microcell Electronics
Nash & Thompson Ltd
Solus-Schall Ltd
Southern Instruments Computer Division
Sperry Gyroscope Co Ltd
Wayne Kerr Laboratories Ltd

Thickness gauges—nucleonic
★ Circle *No 264* on reply card
Associated Automation Ltd
Baldwin Instrument Co Ltd
B & K Laboratories Ltd
Burndept Ltd
Davy & United Engineering Co Ltd
Dawe Instruments
Ekco Electronics Ltd
Evershed & Vignoles Ltd
General Electric Co Ltd, The
Isotope Developments Ltd
Kelvin & Hughes Ltd
Lock & Co Ltd, A. M
Microcell Electronics
Nash & Thompson Ltd
Wayne Kerr Laboratories Ltd

Thickness gauges—ultrasonic
★ Circle *No 265* on reply card
Associated Automation Ltd
B & K Laboratories Ltd
Burndept Ltd
Dawe Instruments Ltd
Ekco Electronics Ltd
Farnell Instruments Ltd
Glass Developments Ltd
Kelvin & Hughes Ltd
Microcell Electronics
Nash & Thompson Ltd
Solus-Schall Ltd
Southern Instruments Computer Division
Teledictor Ltd
Wayne Kerr Laboratories Ltd

Thyratrons
★ Circle *No 266* on reply card
British Thomson-Houston Co Ltd, The
English Electric Valve Co Ltd
Ferranti Ltd
General Electric Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Mullard Ltd
Research & Control Instruments Ltd
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd

Timers & time recorders
★ Circle *No 267* on reply card
Allied Electronics Ltd
Airedale Electrical & Mfg Co Ltd
Applied Radiation Ltd
Associated Automation Ltd
Besson & Robinson Ltd
Boulton Paul Aircraft Ltd
British Federal Welder & Machine Co Ltd
Bristol's Instrument Co Ltd
British Thomson-Houston Co Ltd, The
Burrell & Co Ltd, A. G
Cass & Phillip Ltd
Chamberlain & Hookham Ltd
Craven Electronics Ltd
Davall & Sons Ltd, S
Devon Instruments Ltd
Dunford & Elliott (Sheffield) Ltd
Elcontrol Ltd
Electrical Remote Control Co Ltd
Electronic Instruments Ltd
Electronic Machine Co
Electronic Switchgear (London) Ltd
Elliott Bros (London) Ltd
Ericsson Telephones Ltd
Emeco Electronics Co
Engel & Gibbs Ltd
English Clock Systems Ltd
Everett, Edgcumbe & Co Ltd
Findlay & Co
Furzehill Laboratories Ltd
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
General Radiological Ltd
Graseby Instruments Ltd
Hendrey Relays Ltd
Herbert Ltd, Alfred
Hilton Electric Co Ltd
Hunt & Mitton Ltd
Integra, Leeds & Northrup Ltd
Igranic Electric Co Ltd
Ilford Ltd
Instruments & Controls Ltd
Isotope Developments Ltd
Kingston Control Systems Ltd
Labgear Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Londex Ltd
Metropolitan-Vickers Electrical Co Ltd
Magnetic Controls Ltd
Marconi Instruments Ltd
Microcell Electronics
Nagard Ltd
Nash & Thompson Ltd
Panax Equipment Ltd
Pye & Co Ltd, W. G
Radiovisor Parent Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Sanders (Electronics) Ltd, W. H
Shackman & Sons Ltd, D
Sargrove Electronics Ltd
Sauter Controls Ltd
Sangamo Weston Ltd
Smiths Industrial Instrument Division
South London Electrical Equipment Co Ltd
Sterling Instruments Ltd
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Teledictor Ltd
Telemeters Ltd
Telephone Rentals Ltd
Towers & Co Ltd, J. W
Transmission Accessories Ltd
Tylors of London Ltd
Universal Control Equipment Ltd
Venner Ltd
Winston Electronics Ltd

Torque—indicators & controllers
★ Circle *No 268* on reply card
B & K Laboratories Ltd
Gordon & Co Ltd, James
Igranic Electric Co Ltd
Pullin & Co Ltd, R. B
Savage & Parsons Ltd
Smiths Aircraft Instruments Ltd
Thompson Ltd, J. Langham
Vernons Industries Ltd

Torque—measuring equipment
★ Circle *No 269* on reply card
B & K Laboratories Ltd
EMO Instrumentation Ltd
Ferraris (Clerkenwell) Ltd, Fred
Lintronic Ltd
Lock & Co Ltd, A. M
Saunders-Roe Ltd
Siemens Edison Swan Ltd
Solartron Electronic Group Ltd, The

Traffic control systems
★ Circle *No 270* on reply card
General Electric Co Ltd, The
Metropolitan-Vickers Electrical Co Ltd
Pullin & Co Ltd, R. B
Standard Telephones & Cables Ltd
Westinghouse Brake & Signal Co Ltd

Transfer function analysers
★ Circle *No 271* on reply card
General Electric Co Ltd, The
Muirhead & Co Ltd
Servomex Controls Ltd
Solartron Electronic Group Ltd, The

Transformers—constant voltage
★ Circle *No 272* on reply card
Advance Components Ltd
All Power Transformers
Andec Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
B & K Laboratories Ltd
Brentford Transformers Ltd
British Electric Resistance Co Ltd
Correx Communications Equipment (1948) Ltd
Crompton Parkinson Ltd
Electronic Instruments Ltd
English Electric Co Ltd, The
Ether Ltd
Express Transformers & Controls Ltd
Fielden Electronics Ltd
Foster Instruments Ltd
General Electric Co Ltd, The
Gresham Transformers Ltd
Harbrook Engineering Co Ltd, The
Kandem Electrical Ltd
Hackbridge & Hewittic Electric Co Ltd
Harmsworth, Townley & Co
Honeywell Controls Ltd
JD Electronics (Birmingham) Ltd
JV Radio & Television Ltd
Livingston Laboratories Ltd
London Transformer Products Ltd
Metropolitan-Vickers Electrical Co Ltd
PAR Ltd
Research & Control Instruments Ltd
Radiovisor Parent Ltd
Robinson & Partners Ltd, F. C
Thompson Ltd, J. Langham

Transformers—current
★ Circle *No 273* on reply card
All Power Transformers Ltd
Andec Ltd
Appleby & Ireland Ltd
Brentford Transformer Co Ltd
British Thomson-Houston Co Ltd, The
Crompton Parkinson Ltd
Correx Communications Equipment (1948) Ltd
English Electric Co Ltd, The
General Electric Co Ltd, The
Hackbridge & Hewittic Electric Co Ltd
Harmsworth, Townley & Co
Lewis Electric Motors (Maidenhead) Ltd
Plessey Co Ltd, The
Sangamo Weston Ltd
Standard Telephones & Cables Ltd
Vernons Industries Ltd

Transformers—differential
★ Circle *No 274* on reply card
All Power Transformers Ltd
Andec Ltd
Airmec Ltd
British Electric Resistance Co Ltd
Elliott Bros (London) Ltd
Express Transformers & Controls Ltd
Fielden Electronics Ltd
Foster Transformers Ltd
Gresham Transformers Ltd
Hackbridge & Hewittic Electric Co Ltd
Livingston Laboratories Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C

Transformers—instrument
★ Circle *No 275* on reply card
Andec Ltd
Appleby & Ireland Ltd
British Thomson-Houston Co Ltd, The
Cossor Instruments Ltd
Crompton Parkinson Ltd
Cuthbert Ltd, Ralph
Dependable Relay Co

Electronic Instruments Ltd
English Electric Co Ltd, The
Express Transformers & Controls Ltd
Ferranti Ltd
Fielden Electronics Ltd
Gardners Radio Ltd
General Electric Co Ltd, The
General Radiological Ltd
Gresham Transformers Ltd
Hackbridge & Hewittic Electric Co Ltd
Harmsworth, Townley & Co
Honeywell Controls Ltd
Metropolitan-Vickers Electrical Co Ltd
Mullard Ltd
Plessey Nucleonics Ltd
Record Electrical Co Ltd, The
Sangamo Weston Ltd
Smiths Aircraft Instruments Ltd
Standard Telephones & Cables Ltd
Turner Electrical Instruments Ltd, Ernest

Transformers—power
★ Circle *No 276* on reply card
All Power Transformers Ltd
Andec Ltd
Appleby & Ireland Ltd
Aveley Electric Ltd
Brentford Transformer Co Ltd
British Electric Resistance Co Ltd
British Power Transformer Co Ltd, The
British Thomson-Houston Co Ltd, The
Crompton Parkinson Ltd
Correx Communications Equipment (1948) Ltd
English Electric Co Ltd, The
Express Transformers & Controls Ltd
Faraday Electronic Instruments Ltd
Gardners Radio Ltd
General Electric Co Ltd, The
Hackbridge & Hewittic Electric Co Ltd
Harbrook Engineering Co Ltd, The
Harmsworth, Townley & Co
Hirst Electronic Ltd
Lewis Electric Motors (Maidenhead) Ltd
Metropolitan-Vickers Electrical Co Ltd
Plessey Co Ltd, The
Research & Control Instruments Ltd
Standard Telephones & Cables Ltd
Teledictor Ltd
Vernons Industries Ltd

Transformers—r.f
★ Circle *No 277* on reply card
Andec Ltd
Aveley Electric Ltd
Correx Communications Equipment (1948) Ltd
English Electric Co Ltd, The
Faraday Electronic Instruments Ltd
Plessey Co Ltd, The
Standard Telephones & Cables Ltd

Transformers—rotary
★ Circle *No 278* on reply card
Andec Ltd
British Electric Resistance Co Ltd
British Power Transformer Co Ltd, The
British Thomson-Houston Co Ltd, The
Dependable Relay Co
English Electric Co Ltd, The
JV Radio & Television Ltd
Magnetic Devices Ltd
Plessey Co Ltd, The
Power Controls Ltd
Sperry Gyroscope Co Ltd
Vernons Industries Ltd

Transient recorders
★ Circle *No 279* on reply card
Appleby & Ireland Ltd
B & K Laboratories Ltd
Cambridge Instrument Co Ltd
Fairey Air Surveys Ltd
Lock & Co Ltd, A. M
New Electronic Products Ltd
Research & Control Instruments Ltd
Solartron Electronic Group Ltd, The
Southern Instruments Computer Division
Standard Telephones & Cables Ltd
Stonebridge Electrical Co Ltd, The

Transistors
★ Circle *No 280* on reply card
B & K Laboratories Ltd
British Thomson-Houston Co Ltd, The
English Electric Valve Co Ltd
Farnell Instruments Ltd
Ferranti Ltd
General Electric Co Ltd, The
Mullard Ltd
Newmarket Transistor Co Ltd
Plessey Nucleonics Ltd
Pye & Co Ltd, W. G
Salford Electrical Instruments Ltd
Semiconductors Ltd
Siemens Edison Swan Ltd
Standard Telephones & Cables Ltd
Texas Instruments Ltd, (Silicon)
Walter Instruments Ltd
Wykeham & Co Ltd, W

Transistor test sets
★ Circle *No 281* on reply card
Airmec Ltd
Aveley Electric Ltd
Avo Ltd
B & K Laboratories Ltd
Cossor Instruments Ltd
English Electric Co Ltd, The
Farnell Instruments Ltd
General Electric Co Ltd, The
Hatfield Instruments Ltd
Kasama Electronics Ltd
Livingston Laboratories Ltd
Marconi Instruments Ltd
Microcell Electronics
Mullard Equipment Ltd
Research & Control Instruments Ltd
Sanders (Electronics) Ltd, W. H
Semiconductors Ltd
Standard Telephones & Cables Ltd
Technical Ceramics Ltd
Winston Electronics Ltd
WS Electronics (Production) Ltd

Tubing—flexible
★ Circle *No 282* on reply card
Airtech Ltd
Appleby & Ireland Ltd
Avica Equipment Ltd
BTR Industries Ltd
Camlab (Glass) Ltd
Edwards High Vacuum Ltd
Power Auxiliaries Ltd
Power Flexible Tubing Co Ltd, The
Sanders (Electronics) Ltd, W. H
Smiths Industrial Instruments Division
Thermal Syndicate Ltd, The
Towers & Co Ltd, J. W

Tubing—glass
★ Circle *No 283* on reply card
Appleby & Ireland Ltd
Camlab (Glass) Ltd
Chance-Pilkington Optical Works
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
Glass Developments Ltd
Jobling & Co Ltd, James A
Langley London Ltd
Moncrieff Ltd, John
Rotameter Mfg Co Ltd
Towers & Co Ltd, J. W
Townson & Mercer Ltd
Zeal Ltd, G. H

Tubing—metallic
★ Circle *No 284* on reply card
Avica Equipment Ltd
Accles & Pollock Ltd
BTR Industries Ltd
Ellay Tubes Ltd
Johnson Matthey & Co Ltd
Power Auxiliaries Ltd

Tubing—plastic
★ Circle *No 285* on reply card
Airtech Ltd
BTR Industries Ltd
Camlab (Glass) Ltd
Day & Co (Derby Works) Ltd, J
Ega Electric Ltd
General Electric Co Ltd, The
Langley London Ltd
Towers & Co Ltd, J. W
Wilkinson Rubber Linatex Ltd
X-Lon Products Ltd

Tubing—refractory
★ Circle *No 286* on reply card
Thermal Syndicate Ltd, The
Towers & Co Ltd, J. W

Tubing—rubber
★ Circle *No 287* on reply card
Airtech Ltd
Appleby & Ireland Ltd
Avica Equipment Ltd
BTR Industries Ltd
Camlab (Glass) Ltd
Edwards High Vacuum Ltd
Gallenkamp & Co Ltd, A
Smiths Industrial Instruments Ltd
Towers & Co Ltd, J. W

Ultrasonic industrial equipment
★ Circle *No 288* on reply card
B & K Laboratories Ltd
Dawe Instruments Ltd
Glass Developments Ltd
Kerry's (Ultrasonics) Ltd
Mullard Equipment Ltd
Pye & Co Ltd, W. G
Savage Ltd, W. Bryan
Solus-Schall Ltd
Technical Ceramics Ltd

Ultrasonic instruments
★ Circle *No 289* on reply card
Bailey Meters & Controls Ltd
B & K Laboratories Ltd

Cossor Instruments Ltd
Dawe Instruments Ltd
General Radiological Ltd
Glass Developments Ltd
Kelvin & Hughes Ltd
Kerry's (Ultrasonics) Ltd
Mullard Equipment Ltd
Solus-Schall Ltd
Technical Ceramics Ltd
Venner Electronics Ltd

Ultra-violet sources
★ Circle *No 290* on reply card
Beck Ltd, R & J
Engelhard Industries Ltd (Hanovia Lamps Division)
Gallenkamp & Co Ltd, A
General Electric Co Ltd, The
General Radiological Ltd
Griffin & George Ltd
Hilger & Watts Ltd
McKellen Automation Ltd
Panax Equipment Ltd
Pullin & Co Ltd, R. B
Research & Control Instruments Ltd
Siemens Edison Swan Ltd
Thermal Syndicate Ltd, The
Winston Electronics Ltd

Vacuum indicators, controllers & recorders
★ Circle *No 291* on reply card
Accurate Recording Instrument Co, The
Appleby & Ireland Ltd
Associated Automation Ltd
Bailey Meters & Controls Ltd
Barnet Instruments Ltd
Black Automatic Controls Ltd
British Rototherm Co Ltd
Bristol's Instrument Co Ltd
British Arca Regulators Ltd
Cambridge Instrument Co Ltd
Coley Thermometers Ltd
Drayton Regulator & Instrument Co Ltd
Danfoss Mfg Co
Edwards High Vacuum Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fisher Governor Co Ltd
Foxboro-Yoxall Ltd
Honeywell Controls Ltd
KDG Instruments Ltd
Kent Ltd, George
Londex Ltd
Metropolitan-Vickers Electrical Co Ltd
Negretti & Zambra Ltd
Pye & Co Ltd, W. G
Reavell & Co
Short & Mason Ltd
Smiths Industrial Instrument Division
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thompson Ltd, J. Langham
Thermocontrol Installations Co Ltd
Towers & Co Ltd, J. W
Watford Electric & Mfg Co Ltd

Valves—operated by electric motor
★ Circle *No 292* on reply card
Appleby & Ireland Ltd
Babcock & Wilcox Ltd
Bailey & Co Ltd, Sir W. H
Blakeborough & Sons Ltd, J
British Steam Specialities Ltd
Conveyancer Fork Trucks Ltd
Dewrance & Co Ltd
Fairey Aviation Co Ltd, The
Foster Instrument Co Ltd
Glenfield & Kennedy Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Ham, Baker & Co Ltd
Harland Engineering Co Ltd
High Pressure Components Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Leybold Vacuum Sales Ltd
Martonair Ltd
NGN Electrical Ltd
Rheostatic Co Ltd, The
Ryder & Co (Manchester) Ltd, Thomas
Saunders Valve Co Ltd
Sauter Controls Ltd
Stonebridge Electrical Co Ltd, The
Thermocontrol Installations Co Ltd
Teddington Industrial Equipment Ltd

Valves—hydraulically operated
★ Circle *No 293* on reply card
Airtech Ltd
Alexander Controls Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Bailey & Co Ltd, Sir W. H
Birfield Industries Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J

Ltd
Ltd

British Ermeto Corporation Ltd
Chamberlain Industries Ltd
Crosby Valve & Engineering Co Ltd
Conveyancer Fork Trucks Ltd
DEV Engineering Co Ltd, The
Drayton Regulator & Instrument Co Ltd
Electro-Hydraulics Ltd
Elliott Bros (London) Ltd
Fairey Aviation Co Ltd, The
Fisher Governor Co Ltd
Fraser & Co Ltd, Andrew
Glenfield & Kennedy Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Harland Engineering Co Ltd
High Pressure Components Ltd
Honeywell Controls Ltd
Hunt & Mitton Ltd
Hydraulics & Pneumatics Ltd
Integral Ltd
Kent Ltd, George
Martonair Ltd
Plessey Co Ltd, The
Reilly Engineering Ltd
Ryder & Co (Manchester) Ltd
Samson Controls (London) Ltd
Sauter Controls Ltd
Saunders Valve Co Ltd
Short Bros & Harland Ltd
Sperry Gyroscope Co Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Williams & James (Engineers) Ltd

Valves—manually operated
★ Circle *No 294* on reply card
Appleby & Ireland Ltd
Baldwin Instrument Co Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
DEV Engineering Co Ltd, The
Elliott Bros (London) Ltd
Gloster Aircraft Co Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
High Pressure Components Ltd
Teddington Industrial Equipment Ltd
Transmission Accessories Ltd

Valves—pneumatically operated
★ Circle *No 295* on reply card
Air Automation Ltd
Alexander Controls Ltd
Appleby & Ireland Ltd
Bailey & Co Ltd, Sir W. H
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
Birfield Industries Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
DEV Engineering Co Ltd, The
Dewrance & Co Ltd
Drayton Regulator & Instrument Co Ltd
Electro-Hydraulics Ltd
Elliott Bros (London) Ltd
Fisher Governor Co Ltd
Globe Pneumatic Engineering Co Ltd
Glenfield & Kennedy Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
Harland Engineering Co Ltd
High Pressure Components Ltd
Honeywell Controls Ltd
Hunt & Mitton Ltd
Hydraulics & Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Kent Ltd, George
Lang Pneumatic Ltd
Leybold Vacuum Sales Ltd
Martonair Ltd
Perl Controls Ltd
Reilly Engineering Ltd
Ryder & Co (Manchester) Ltd, Thomas
Samson Controls (London) Ltd
Sauter Controls Ltd
Saunders Valve Co Ltd
Sperry Gyroscope Co Ltd
Taylor Controls Ltd
Transmission Accessories Ltd
Telektron (GB) Ltd
Teddington Industrial Equipment Ltd
Williams & James (Engineers) Ltd

Valves—solenoid operated
★ Circle *No 296* on reply card
Airtech Ltd
Alexander Controls Ltd
Baldwin Instrument Co Ltd
Bell Precision Engineering Ltd
B & K Laboratories Ltd
Black Automatic Controls Ltd
British Thermostat Co Ltd
Danfoss Mfg Co
Dowty Nucleonics Ltd
Electro-Hydraulics Ltd
Ether Ltd
Fawcett-Finney Ltd
Fisher Governor Co Ltd
Flight Refuelling Ltd
Glenfield & Kennedy Ltd
Gloster Aircraft Co Ltd
Harland Engineering Co Ltd
Hartley Electromotives Ltd
Howden & Co Ltd, James
Hunt & Mitton Ltd
Igranic Electric Co Ltd
Industrial Pyrometer Co Ltd, The
Keelavite Rotary Pumps & Motors Ltd
Lock & Co Ltd, A. M
Magnetic Equipment Co Ltd, The
Magnetic Valve Co Ltd, The
New Electronic Products Ltd
Nottingham Thermometer Co Ltd
Plessey Co Ltd, The
Rheostatic Co Ltd, The
Sauter Controls Ltd
Teddington Aircraft Controls Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Vickers-Armstrongs (Engineers) Ltd
Western Mfg (Reading) Ltd
Williams (Birmingham) Ltd, R. A

Valves—steam operated
★ Circle *No 297* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
Birfield Industries Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
Drayton Regulator & Instrument Co Ltd
Fisher Governor Co Ltd
Gordon & Co Ltd, James
High Pressure Components Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hunt & Mitton Ltd
Kent Ltd, George
Kingston Control Systems Ltd
Reilly Engineering Ltd
Sauter Controls Ltd
Sperry Gyroscope Co Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Williams & James (Engineers) Ltd

Valves—thermostatically operated
★ Circle *No 298* on reply card
Appleby & Ireland Ltd
Black Automatic Controls Ltd
Conveyancer Fork Trucks Ltd
Danfoss Mfg Co
General Electric Co Ltd, The
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
High Pressure Components Ltd
Honeywell Controls Ltd
Kingston Control Systems Ltd
Ryder & Co (Manchester) Ltd, Thomas
Perl Controls Ltd
Samson Controls (London) Ltd
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd

Valves (air)—flow
★ Circle *No 299* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Birfield Industries Ltd
BEN Patents Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
DEV Engineering Co Ltd, The
Danfoss Mfg Co
Drayton Regulator & Instrument Co Ltd
Elliott Bros (London) Ltd
Firth Cleveland Instruments Ltd
Fisher Governor Co Ltd
Globe Pneumatic Engineering Co Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
High-Pressure Components Ltd
HEC Compressors & Engines Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hydraulics & Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Hunt & Mitton Ltd
Kent Ltd, George
Magnetic Valve Co Ltd, The
Payne & Griffiths Ltd
Platon Ltd, G. A
Plessey Co Ltd, The
Pressure Control Ltd
Samson Controls (London) Ltd
Sauter Controls Ltd
Simmonds Aerocessories Ltd
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Western Mfg (Reading) Ltd
X-Lon Products Ltd

Valves (air)—non-return
★ Circle *No 300* on reply card
Appleby & Ireland Ltd
Baldwin Instrument Co Ltd
Blakeborough & Sons Ltd, J
Conveyancer Fork Trucks Ltd
Danfoss Mfg Co
Elliott Bros (London) Ltd
Gloster Aircraft Co Ltd
HEC Compressors & Engines Ltd
High-Pressure Components Ltd
Hopkinsons Ltd
Hymatic Engineering Co Ltd, The
Plessey Co Ltd, The
Pressure Control Ltd
Taylor Controls Ltd

Valves (air)—pressure regulating
★ Circle *No 301* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Birfield Industries Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
DEV Engineering Co Ltd, The
Drayton Regulator & Instrument Co Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Fisher Governor Co Ltd
Gloster Aircraft Co Ltd
Globe Pneumatic Engineering Co Ltd
Gordon & Co Ltd, James
HEC Compressors & Engines Ltd
High Pressure Components Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hunt & Mitton Ltd
Hymatic Engineering Co Ltd, The
Industrial Pyrometer Co Ltd
Kent Ltd, George
Norgren Ltd, C. A
Payne & Griffiths Ltd
Platon Ltd, G. A
Plessey Co Ltd, The
Pressure Control Ltd
Samson Controls (London) Ltd
Sauter Controls Ltd
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Western Mfg (Reading) Ltd
Williams & James (Engineers) Ltd

Valves (air)—safety & relief
★ Circle *No 302* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
Fisher Governor Co Ltd
Gloster Aircraft Co Ltd
HEC Compressors & Engines Ltd
High Pressure Components Ltd
Hunt & Mitton Ltd
Hydraulics & Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Industrial Pyrometer Co Ltd
Magnetic Valve Co Ltd, The
Perl Controls Ltd
Plessey Co Ltd, The
Pressure Control Ltd
Taylor Controls Ltd
Western Mfg (Reading) Ltd
Williams & James (Engineers) Ltd

Valves (electronic)
★ Circle *No 303* on reply card
Appleby & Ireland Ltd
Automatic Telephone & Electric Co Ltd
B & K Laboratories Ltd
British Sarozal Ltd
British Thomson-Houston Co Ltd, The
Elliott Bros (London) Ltd
EMI Electronics Ltd
Ericsson Telephones Ltd
English Electric Valve Co Ltd
Ferranti Ltd
General Radiological Ltd
General Electric Co Ltd, The
Hivac Ltd
Livingston Laboratories Ltd
Mullard Ltd
Siemens Edison Swan Ltd
"Solus" Electronic Tubes Ltd, The
Standard Telephones & Cables Ltd

★ *For further details circle on card facing page A60*

Valves (liquid)—flow
★ Circle *No 304* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Avery-Hardoll Ltd
Bailey Meters & Controls Ltd
Baldwin Instrument Co Ltd
Birfield Industries Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
DEV Engineering Co Ltd, The
Dowty Equipment Ltd
Drayton Regulator & Instrument Co Ltd
Elliott Bros (London) Ltd
Fairey Aviation Co Ltd, The
Firth Cleveland Instruments Ltd
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
High Pressure Components Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hunt & Mitton Ltd
Hydraulics & Pneumatics Ltd
Integral Ltd
Kent Ltd, George
Lock & Co Ltd, A. M
Magnetic Valve Co Ltd, The
Payne & Griffiths Ltd
Platon Ltd, G. A
Plessey Co Ltd, The
Pressure Control Ltd
Rheostatic Co Ltd, The
Samson Controls (London) Ltd
Sauter Controls Ltd
Short Bros & Harland Ltd
Simmonds Aerocessories Ltd
Spenborough Engineering Co Ltd
Sperry Gyroscope Co Ltd
Stein Atkinson Vickers Hydraulics Ltd
Stonebridge Electrical Co Ltd, The
Taylor Controls Ltd
Teddington Industrial Equipment Ltd
Thermocontrol Installations Co Ltd
Watford Electric & Mfg Co Ltd
Western Mfg (Reading) Ltd
X-Lon Products Ltd

Valves (liquid)—non-return
★ Circle *No 305* on reply card
Appleby & Ireland Ltd
Baldwin Instrument Co Ltd
Birfield Industries Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Danfoss Mfg Co
Dowty Equipment Ltd
Elliott Bros (London) Ltd
Fairey Aviation Co Ltd, The
Gloster Aircraft Co Ltd
Gordon & Co Ltd, James
High Pressure Components Ltd
Hopkinsons Ltd
Hydraulics & Pneumatics Ltd
Integral Ltd
Plessey Co Ltd, The
Pressure Control Ltd
Short Bros & Harland Ltd
Spenborough Engineering Co Ltd
Stein Atkinson Vickers Hydraulics Ltd
Williams & James (Engineers) Ltd

Valves (liquid)—pressure regulating
★ Circle *No 306* on reply card
Alexander Controls
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Birfield Industries Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
British Ermeto Corporation Ltd
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
DEV Engineering Co Ltd, The
Dowty Equipment Ltd
Drayton Regulator & Instrument Co Ltd
Electroflo Meters Co Ltd
Elliott Bros (London) Ltd
Fairey Aviation Co Ltd, The
Fisher Governor Co Ltd
Gloster Aircraft Co. Ltd
Gordon & Co Ltd, James
High Pressure Components Ltd
Honeywell Controls Ltd
Hopkinsons Ltd
Hunt & Mitton Ltd
Hydraulics & Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Industrial Pyrometer Co Ltd
Integral Ltd
Norgren Ltd, C. A
Payne & Griffiths Ltd
Platon Ltd, G. A
Plessey Co Ltd, The
Samson Controls (London) Ltd
Sauter Controls Ltd
Spenborough Engineering Co Ltd
Sperry Gyroscope Co Ltd
Stein Atkinson Vickers Hydraulics Ltd
Taylor Controls Ltd
Thermocontrol Installations Co Ltd
Western Mfg (Reading) Ltd
Williams & James (Engineers) Ltd

Valves (liquid)—safety & relief
★ Circle *No 307* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Black Automatic Controls Ltd
Blakeborough & Sons Ltd, J
Conveyancer Fork Trucks Ltd
Crosby Valve & Engineering Co Ltd
Dowty Equipment Ltd
DEV Engineering Co Ltd, The
Fairey Aviation Co Ltd, The
Fisher Governor Co Ltd
Gloster Aircraft Co Ltd
High Pressure Components Ltd
Honeywell Controls Ltd
Hunt & Mitton Ltd
Hydraulics & Pneumatics Ltd
Hymatic Engineering Co Ltd, The
Industrial Pyrometer Co Ltd
Integral Ltd
Magnetic Valve Co Ltd, The
Perl Controls Ltd
Plessey Co Ltd, The
Pressure Control Ltd
Spenborough Engineering Co Ltd
Sperry Gyroscope Co Ltd
Stein Atkinson Vickers Hydraulics Ltd
Taylor Controls
Western Mfg (Reading) Ltd
Williams & James (Engineers) Ltd

Valve positioners
★ Circle *No 308* on reply card
Alexander Controls Ltd
Appleby & Ireland Ltd
Bailey Meters & Controls Ltd
Black Automatic Controls Ltd
Crosby Valve & Engineering Co Ltd
Drayton Regulator & Instrument Co Ltd
Electronic Switchgear (London) Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fisher Governor Co Ltd
Foxboro-Yoxall Ltd
Gordon & Co Ltd, James
Integra, Leeds & Northrup Ltd
Kent Ltd, George
Kandem Electrical Ltd
Magnetic Valve Co Ltd, The
Negretti & Zambra Ltd
Research & Controls Ltd
Samson Controls (London) Ltd
Sauter Controls Ltd
Smiths Aircraft Instruments Ltd
Stonebridge Electrical Co Ltd, The
Sunvic Controls Ltd
Taylor Controls Ltd
Teleflex Products Ltd
Telektron (GB) Ltd
Telemeters Ltd

Valve testers—electronic
★ Circle *No 309* on reply card
All-Power Transformers Ltd
Avo Ltd
B & K Laboratories Ltd
British Sarozal Ltd
Cossor Instruments Ltd
Craven Electronic Ltd
Farnell Instruments Ltd
Livingston Laboratories Ltd
Mullard Equipment Ltd
Rank Cintel Ltd
Solartron Electronic Group Ltd, The
Taylor Electrical Instruments Ltd

Vibration pick-ups
★ Circle *No 310* on reply card
Aveley Electric Ltd
B & K Laboratories Ltd
Cawkell Research & Electronics Ltd
Craven Electronics Ltd
Dawe Instruments Ltd
De Havilland Aircraft Co Ltd
EMI Electronics Ltd
Farnell Instruments Ltd
Furzehill Laboratories Ltd
Gloster Aircraft Co Ltd
Goodman's Industries Ltd
Lancashire Dynamo Electronic Products Ltd
Measuring Instruments (Pullin) Ltd
Research & Control Instruments Ltd
Savage Ltd, W. Bryan
Southern Instruments Computer Division
Wayne Kerr Laboratories Ltd

Vibration generators
★ Circle *No 311* on reply card
B & K Laboratories Ltd
Dawe Instruments Ltd
EMI Electronics Ltd
Farnell Instruments Ltd
Goodmans Industries Ltd
Hendrey Relays Ltd
Lancashire Dynamo Electronics Products Ltd
Livingston Laboratories Ltd
Lion Electronic Developments Ltd
Microcell Electronics
Research & Control Instruments Ltd
Sargrove Electronics Ltd
Savage Ltd, W. Bryan
Thompson Ltd, J. Langham

Vibration testing equipment
★ Circle *No 312* on reply card
Aveley Electric Ltd
B & K Laboratories Ltd
Dawe Instruments Ltd
Elliott Bros (London) Ltd
EMI Electronics Ltd
Endecotts (Filters) Ltd
Farnell Instruments Ltd
Gloster Aircraft Co Ltd
Goodmans Industries Ltd
Instruments & Controls Ltd
Lyons Ltd, Claude
Muirhead & Co Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Savage Ltd, W. Bryan
Solartron Electronic Group Ltd, The
Shandon Scientific Co Ltd
Thompson Ltd, J. Langham
Wayne Kerr Laboratories Ltd
Wickman Ltd

Viscosity measuring equipment
★ Circle *No 313* on reply card
Camlab (Glass) Ltd
Elliott Bros (London) Ltd
Elliott Ltd, H. J
Ferranti Ltd
Gallenkamp & Co Ltd, A
Gordon & Co Ltd, James
Griffin & George Ltd
Jobling & Co Ltd, James A
Laboratory Equipment (London) Ltd
Lancashire Dynamo Electronic Products Ltd
Research Utilities Ltd
Short & Mason Ltd
Towers & Co Ltd, J. W
Wykeham & Co Ltd, W

Voltage regulators
★ Circle *No 314* on reply card
Advance Components Ltd
Airmec Ltd
B & K Laboratories Ltd
Brentford Transformers Ltd
British Electric Resistance Co Ltd, The
British Power Transformer Co Ltd
British Thomson-Houston Co Ltd, The
Cox-Walkers Ltd
Dubilier Condenser Co (1925) Ltd
Electric Construction Co Ltd, The
Electro Methods Ltd
English Electric Co Ltd, The
English Electric Valve Co Ltd
Fielden Electronics Ltd
Ferranti Ltd
Foster Transformers Ltd
Kasama Electronics Ltd
Lancashire Dynamo Electronic Products Ltd
Livingston Laboratories Ltd
Metropolitan-Vickers Electrical Co Ltd
Rank Cintel Ltd
Research & Control Instruments Ltd
Robinson & Partners Ltd, F. C
Sanders (Electronics) Ltd, W. H
Sargrove Electronics Ltd
Servomex Controls Ltd
Standard Telephones & Cables Ltd
Thompson Ltd, J. Langham
Winston Electronics Ltd

Weight indicators, controllers & recorders
★ Circle *No 315* on reply card
Adequate Weighers Ltd
Appleby & Ireland Ltd
Avery Ltd, W. & T
Cambridge Instrument Co Ltd
Davy & United Engineering Co Ltd
Dunford & Elliott (Sheffield) Ltd
Elliott Bros (London) Ltd
Evershed & Vignoles Ltd
Fielden Electronics Ltd
Parsons & Co Ltd, S
Research & Control Instruments Ltd
Sargrove Electronics Ltd
Simon Ltd, Henry
Sinex Engineering Co Ltd
Solartron Electronic Group Ltd, The
Taylor Controls Ltd
Thompson Ltd, J. Langham
Western Mfg (Reading) Ltd

Wind direction indicators
★ Circle *No 316* on reply card
B & K Laboratories Ltd
Everett, Edgcumbe & Co Ltd
Evershed & Vignoles Ltd

Wobbulators
★ Circle *No 317* on reply card
Airmec Ltd
Aveley Electric Ltd
B & K Laboratories Ltd
Cossor Instruments Ltd
Farnell Instruments Ltd
Leland Instruments Ltd
Livingston Laboratories Ltd
Research & Control Instruments Ltd
Smurthwaite Electronics
Taylor Electrical Instruments Ltd

X-ray equipment
★ Circle *No 318* on reply card
General Electric Co Ltd, The
General Radiological Ltd
Hilger & Watts Ltd
Joyce, Loebl & Co Ltd
Labgear Ltd
Marconi Instruments Ltd
Metropolitan-Vickers Electrical Co Ltd
Pullin & Co Ltd, R. B
Research & Control Instruments Ltd
Solus-Schall Ltd
Unicam Instruments Ltd
Wykeham & Co Ltd, W

X-ray tubes
★ Circle *No 319* on reply card
B & K Laboratories Ltd
English Electric Valve Co Ltd
Ferranti Ltd
General Electric Co Ltd, The
General Radiological Ltd
Hilger & Watts Ltd
Ilford Ltd
Isotope Developments Ltd
Mullard Ltd
Newton Victor Ltd
Research & Control Instruments Ltd
"Solus" Electronic Tubes Ltd, The
Solus-Schall Ltd
Standard Telephones & Cables Ltd

Yaw meters
★ Circle *No 320* on reply card
Airflow Developments Ltd
Electro Mechanisms Ltd
Gloster Aircraft Co Ltd
Hendrey Relays Ltd